University of Southern Queensland

Faculty of Health, Engineering and Sciences

Effective Road Pavement Reconstruction in the Fraser Coast Region QLD

A dissertation submitted by

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ENG4111 and 4112 Research Project

towards the degree of

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Abstract

The Fraser Coast is located in the Wide Bay Burnett Region, Queensland, approximately 250km north of Brisbane and spans an area of 7,105km^2 with a population density of 15 people per square kilometre. The region is developed on expansive soil, alluvium deposits and sand. The Fraser Coast Regional Council, the local authority in the region, undertakes a programme of road reconstructions each year as part of their capital works programme.

This dissertation sought to critically evaluate the road reconstruction practices at the Fraser Coast Regional Council and determine the effectiveness of the pavement profiles used while suggesting alternative options. This was done by identifying eight (8) roads which had been reconstructed within the last 10 years and obtaining all as constructed and project data. Site investigations were then undertaken to evaluate the existing pavement conditions and then compared with the laser profilometer data from 2017.

The investigation revealed the performance of reconstructed pavements in the region was varied with many roads demonstrating failures and surface distress. Design checks were undertaken to verify the pavement designs and it was found that generally they were sufficient for the input parameters, demonstrating sound design practices. However, the investigation revealed that the design traffic and traffic growth assumptions were often incorrect, meaning that in some cases the pavement designs could be improved. Construction and material issues are the likely causes of distress in failed pavements with correctly assumed design input parameters.

While the council has been successful in many aspects of the reconstruction process, it is imperative that they ensure accurate design assumptions and input data to feed into their established design procedure. Continued due diligence in the construction phase in the form of quality assurance, audit testing and site inspections should be adequate to ensure the conformance of pavements to specification. This process will help alleviate the possibility of premature degradation of suitably designed pavement structures.

This dissertation also sought to conduct a life cycle cost analysis (LCCA) on three (3) alternative pavement designs to consider their suitability to the Fraser Coast. The options included one unbound granular, one modified granular and one concrete pavement. The LCCA ultimately found that of the alternative designs, the modified granular pavement with lightly bound CTB subbase represented the most value over its life cycle.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged. I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Kaz Chapman-Vagg

Student Number: [redacted]

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Chapter 1 - Introduction

Road networks have a long history and are essential to connect communities and encourage social cohesiveness while also facilitating trade and commerce. Throughout history, the method of building roads has undergone significant changes due to advances in technology and changes in needs including the use of vehicles. However, at the centre of the drive to build and maintain roads is the desire to ensure fast transport of people and goods between communities.

History tells us that the Roman Empire were pioneers in the construction of roads, dating back approximately 1800 years. While not for civilian transport, the roads were constructed to allow for movement of military forces and equipment across Europe. Indeed, these revered road builders were able to apply advanced principles and techniques such that some of the roads still exist today. This is possible due to the great pavement depths they achieved, which are built on solid and sometimes improved subgrade. Of course, this depth of pavement and quantity of material is not practical in the modern world due to financial constraints.

The arteries of the Australian transport system is the road and highway network, which dates back to 1815, in the early days of the English Settlement. The road network spans approximately 870 000 km around the country and is used by most Australians on a daily basis with approximately 9 million households owning at least one car. According to data provided by the Department of Infrastructure, the Australian Government at all levels spends tens of billions of dollars per year on road infrastructure. Indeed, with such a significant portion of the Commonwealth's budget being spent on roads it is vital to ensure that taxpayers are receiving value for money (Australian census, 2016; Australian Department of Infrastructure; 2018).

" Road transport infrastructure is critical to sustaining Australian communities, growing our strong economy and improving our international competitiveness." (Australian Department of Infrastructure, 2018).

As suggested by the Australian Department of Infrastructure, there is a strong need to construct, maintain and improve Australia's road network for transport, economic and safety reasons. Each road in the Australian road network needs to be designed on an individual basis and constructed in the most cost effective manner while also meeting the needs of those who use it. Local governments are typically responsible for the construction of urban and regional roads while main arterial roads and highways fall under the authority of the state.

The Fraser Coast is located in the Wide Bay Burnett Region, Queensland, approximately 250km north of Brisbane and home to the internationally renowned Fraser Island. The local authority in the region is the Fraser Coast Regional Council (FCRC) which was established in 2006 following the amalgamation of Maryborough, Hervey Bay, Tiaro and Woocoo Shire Councils. The region spans an area of approximately 7,105 km2 and services a population of 105,000 people. As such, the council has the responsibility of ensuring the provision of quality road infrastructure to a widely spread and geographically diverse community.

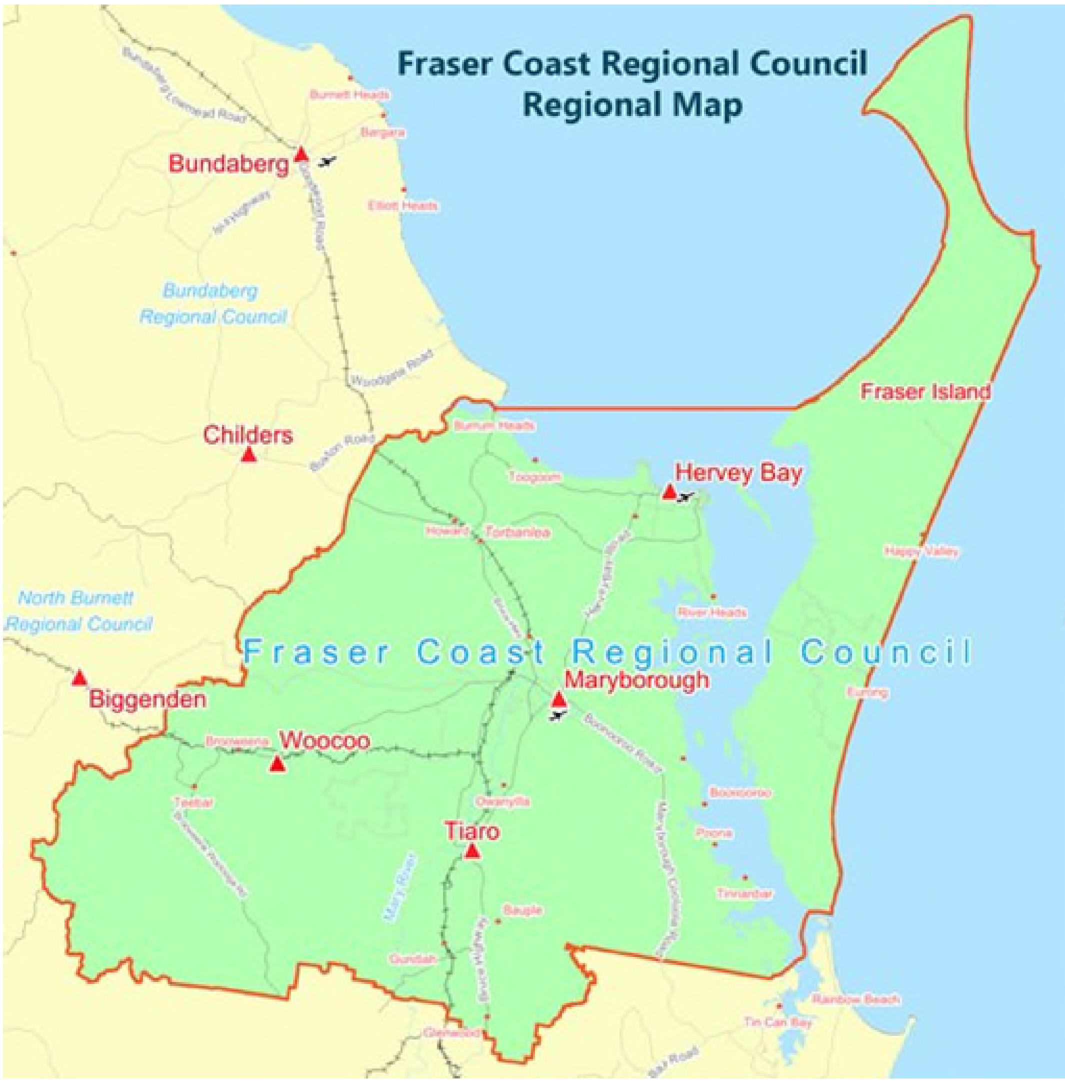

Figure 1.0: Map of Fraser Coast Region (FCRC, 2020)

From the year 2001, the population of the Fraser Coast has grown by 36% and is projected to grow by a further 21% to the year 2036, causing increased pressure on the already stressed and aging road network. The Fraser Coast has a population density of approximately 15 people per square km while in comparison Brisbane City Region has a density of approximately 917 people per square km and the Sunshine Coast Region has a density of 141 people per square km. Although the Fraser Coast region doesn't require a road network with the same capacity as Brisbane or Sunshine Coast, it does have a much greater span and evidently has less residents to pay for road upgrades and maintenance.

The Fraser Coast Regional Council in the 2019/2020 financial year had a total annual budget of $335 Million with a significant $40 Million allocated for road asset capital works projects. A significant portion of this capital budget will go to maintaining the aging 3000km road network which consists of approximately 817km of unsealed roads (FCRC, 2020).

Due to the widespread extents of the Fraser Coast region, there is a range of pavement types, configurations and formations in order to service the needs of all residents. Indeed, the road network contains urban, residential and also a significant amount of rural roads which carry varying volumes of traffic.

The majority of road pavements in the region are flexible pavements with bituminous surfacing or asphalt, with some minor rigid pavements for floodways. Primarily, asphalt surfacing is reserved for high traffic urban roads and some residential while most roads have a bitumen seal due to financial constraints.

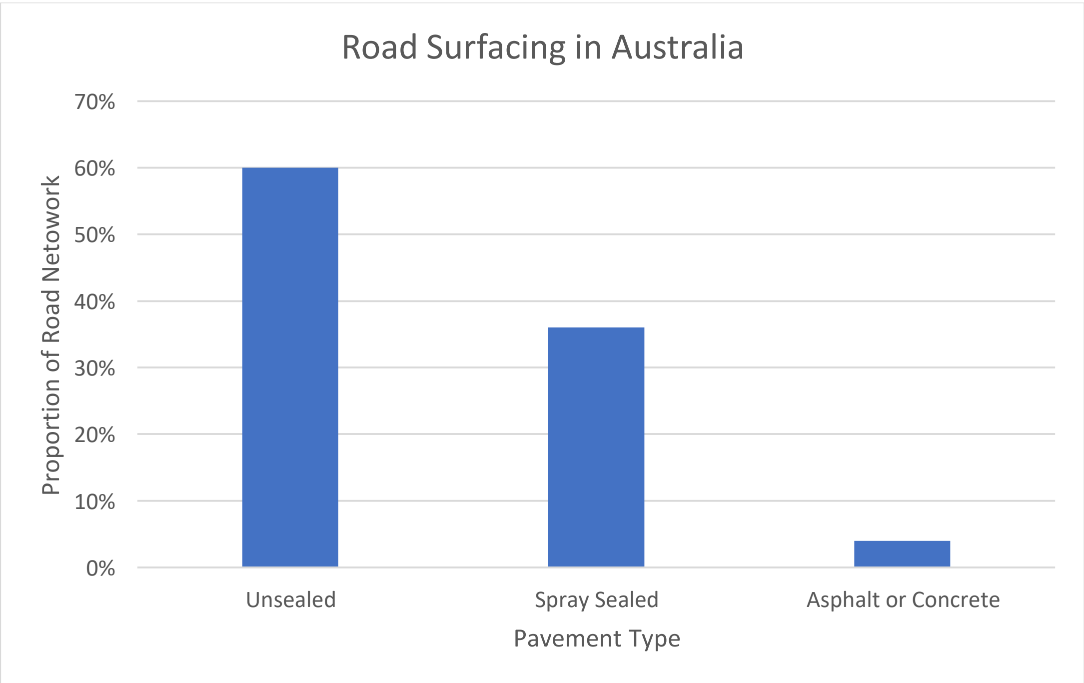

Figure 1.1: Road Surfacing in Australia (IPWEA, 2017)

The following chapters in this dissertation will outline the gap in research which has been identified, relevant literature and a proposed methodology. Furthermore, detail will be provided of the project outcomes, discussion and conclusions as well as recommendations and further research.

Chapter 2 - Problem Identification

Due to the aging nature of the road network in the Fraser Coast, there is an increasing volume of failed roads which are identified for reconstruction. This incurs a significant financial cost to the local government and requires a rigorous road reconstruction program. Looking to the future, it is increasingly important for the Fraser Coast Regional Council to reconstruct roads in the most economically sensible manner which will allow for the most effective construction and maintenance programs.

One of the primary causes of pavement failure in any road is the ingress of water through the surface or shoulders, leading to potholes and a weakened pavement structure. This highlights the importance of maintaining an impervious surface and adequate roadside drainage structures. Considering the age of the region dates back to the late 1800's, there is commonly poor stormwater drainage and damaged kerb and channel in much of the older suburbs. As such, under even minor weather conditions, there is limited capacity for the water to escape to the stormwater system causing it to pool in the kerb and on the road surface.

Over time, as the population grew and demand on the road network also grew, so did the need for more regular maintenance including the need for resurfacing. This increased demand caused the condition of road pavements across the region to decline due to the limited resources of some local authorities prior to amalgamation in 2008.

FCRC has the task of ensuring that failed roads are reconstructed in the most cost effective way over the serviceable lifetime of the road in order to meet current and future demands for the region. Due to the very low population density, it is important to construct roads which are not just fit for purpose, but offer the most benefit over their life cycle. It is expected that by determining the most effective pavement profiles for use in road reconstructions in the Fraser Coast, that there will ultimately be a significant financial benefit to the council over the life of the pavement. This will provide a substantial and tangible benefit to the wider community as it will allow for greater maintenance and upkeep of the existing road network into the future.

As such, this dissertation seeks to investigate the current methods and practices in pavement reconstructions and determine the most effective pavement profile for use in the Fraser Coast region.

Chapter 3 - Literature Review

3.1 Introduction

A literature review has been undertaken to research the current leading types of road pavements used in Australia, their methods for construction and their application in road reconstruction works. This was done in conjunction with a review of the current pavement reconstruction methods used at the Fraser Coast Regional Council, the properties of the available materials and will also contain an investigation into the geology of the region.

To determine the most effective pavement for road reconstructions in the Fraser Coast Queensland, the following topics will be presented:

- Geology of Fraser Coast region
- Pavement types
- Pavement design methods
- Pavement evaluation methods
- Subgrade treatment options for the Fraser Coast and;
- Road building materials available in the Fraser Coast

3.2 Geology of Fraser Coast

The Fraser Coast exhibits a unique geological formation in that it contains varying conditions since the landscape includes coastal and rural areas. This unique landscape primarily supports a large agricultural industry dominated by the production of sugar cane and contains Fraser Island, the world's largest sand island, formed over hundreds of thousands of years where sand was carried to deposit near the mainland.

The Maryborough Basin is the geological basin in which the Fraser Coast is located and covers an area of $24{,}600km^2$. The basin dates back 250 million years to the Mesozoic era with formation of sedimentary rocks, containing seams of black coal, known as the Burrum Coal Measures (Marshall, 2015). Although there is currently no coal or coal seam gas extraction in the region, there is a rich history of coal mining which was used for export via the Urangan Pier, which at the time was one of the longest deep sea piers in Australia.

Willmott (2016) suggests that the first rocks deposited in the region were sandstone, siltstone and mudstone before the coal seams were formed. The Maryborough Basin has one of the thickest accumulations of sedimentary rocks in Australia, to a depth of 6500m which have now been affected by compression and outcrop is many folds. Evidence of these sedimentary rocks can be seen at Point Vernon, Hervey Bay.

Millions of years after the first deposition of rocks in the region, the sedimentary layer was obscured by a thin formation of 34m, known as the Elliot Formation. The Elliot Formation contains materials such as conglomerate, sandstone, siltstone, silty mudstone and shale. Figure 3.1 is an illustration of the geological formation of the Fraser Coast region.

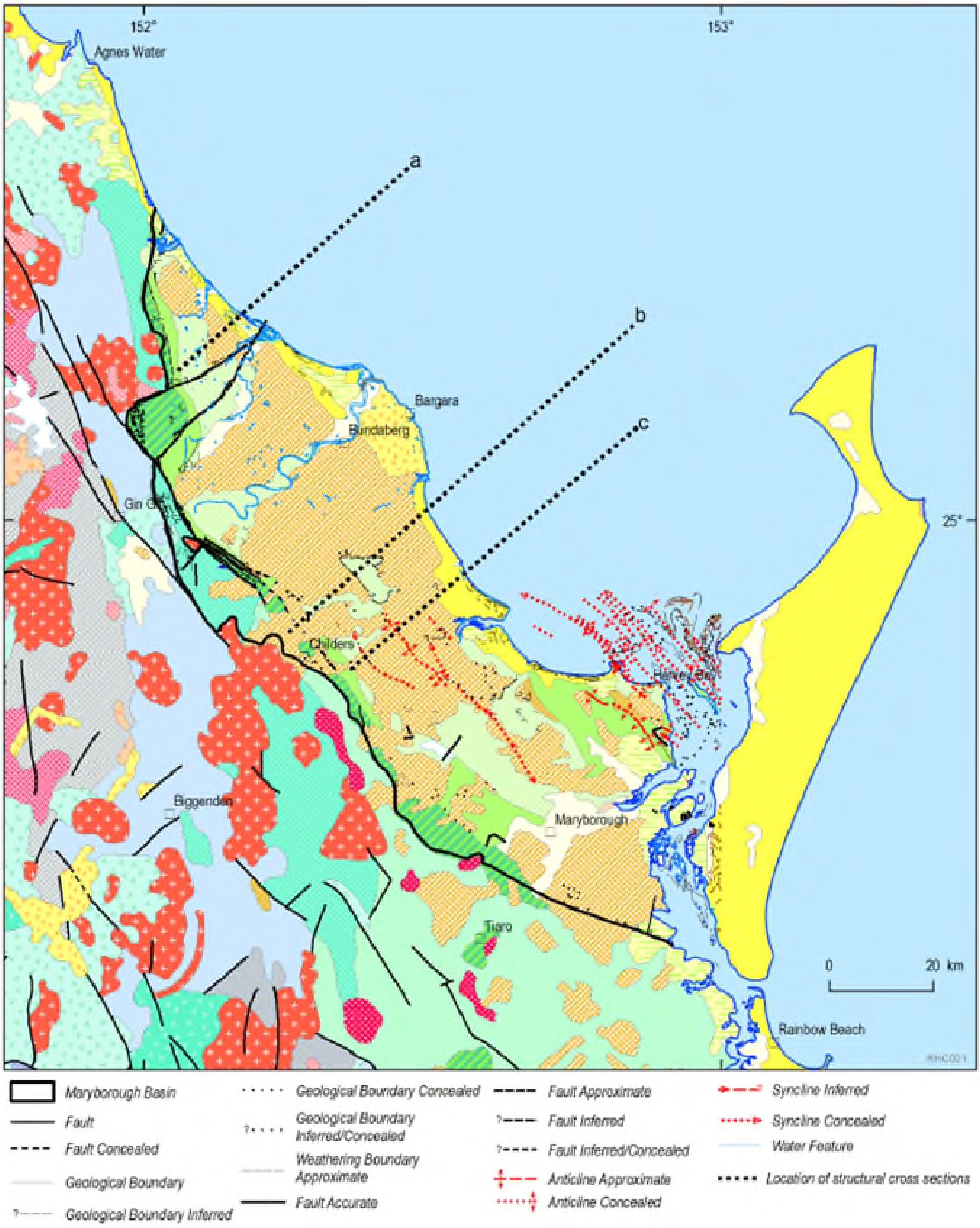

Figure 3.1: Sketch of Fraser Coast Geology (Marshall, 2015).

This research will focus primarily on the population areas of Hervey Bay and Maryborough respectively. Figure 3.2 is a close up illustration of Hervey Bay while Figure 3.3 is a close up illustration of Maryborough.

Figure 3.2: Geological properties of Hervey Bay (Queensland Globe, 2020).

Burrum Coal Measures

- Coal
- Shale
- Siltstone
- Sandstone
- Conglomerate

Maryborough Formation

- Various Siltstones
- Mudstones
- Sandstone
- Arenite

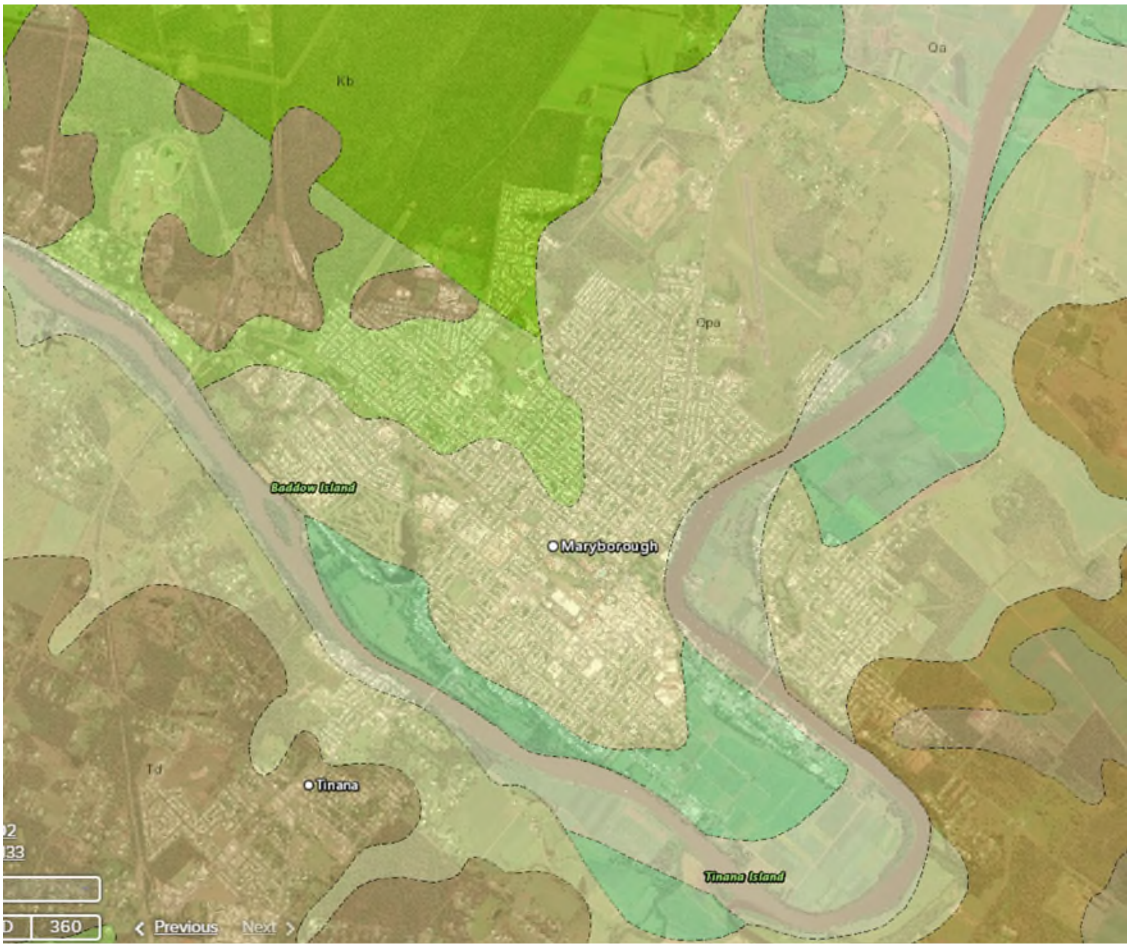

Figure 3.3: Geological Properties of Maryborough (Queensland Globe, 2020).

Alluvium

- Silt
- Sand
- Gravel
- Unconsolidated material
- Clay

Elliot Formation

- Quartzose to sublabile sandstone,
- Conglomerate
- Siltstone
- Mudstone
- Shale

River terrace;

- sand,
- silt,
- clayey gravel

From inspection, it can be seen that the geological properties vary significantly between the two population centres. Indeed, the properties of Hervey Bay indicate the Burrum Coal Measures, combined with the Maryborough Formation, constitute most of the town. This, in conjunction with some sandy material closer to the coast line, alludes to medium strength subgrade materials being present.

On the other hand, the properties of Maryborough indicate the presence some fairly unconsolidated and low quality material as the predominant formation. This suggests that the subgrade materials for road construction will generally be poor. The presence of both clay and silty material in the Maryborough region indicates that the soil is highly moisture sensitive, posing potential problems during construction.

Das (2010) wrote that due to the moisture sensitive nature of clay material, it is subject to changes in volume through expansion and contraction. Furthermore, silty soil can be strong in certain conditions, however when exposed to moisture its strength is significantly depleted and may cause it to collapse (Austroads, 2017).

3.2.1 Expansive Soils

Expansive soils are soil types which are sensitive to moisture and are prone to shrink and swell changes in volume. These volume changes can exert forces on even heavily loaded structures, causing them to be permanently deformed and adding a significant financial burden to those constructing and managing the constructed assets.

It is abundantly clear that the geological conditions present in Maryborough exhibit the qualities and characteristics of expansive and collapsible soils. This is evident when observing the failure modes of road pavements and kerb and channel within the region. Figure 3.4 is an image depicting a common kerb and channel failure in the Fraser Coast.

Figure 3.4: Kerb and Channel failure in Fraser Coast

The rolled back profile of this kerb and the adjacent pavement failure is representative of the effect that expansive soils can have on road infrastructure. Nelson et al. (2015) wrote that expansive soils consist primarily of clay particles which swell when exposed to moisture and shrink when moisture is expelled from the particles. As such, it is of paramount importance to prevent the ingress of water into the pavement and subgrade material while also providing drainage structures to drain moisture (Nelson et al, 2015). This was corroborated by Das (2010) who suggested that the volumetric changes in subgrade can be the greatest cause of duress to pavements (Das, 2010). Figure 3.5 is an illustration of the behaviour of expansive clay when exposed to moisture.

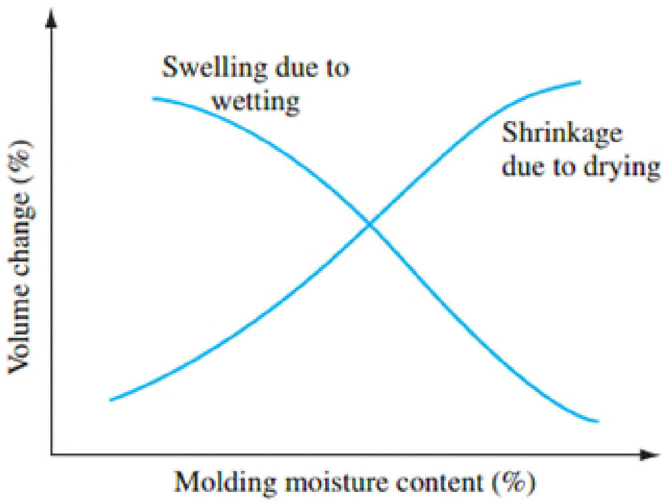

Figure 3.5: Behaviour of expansive clay under moisture changes (Das, 2010).

There are several methods used to identify expansive soils through varying levels of complexity and depth. The most commonly used method to make a determination as to whether a soil may be expansive are the Atterberg limits as determined by a geotechnical investigation. There are two indices defined on the basis of the Atterberg limits, the Plasticity limit (PI) and the liquidity limit (LI), the difference between the two being the plasticity index. Table 3.1 is a demonstration of a materials the expansion potential of a range of PI values.

Table 3.1: Expansion potential of soils and PI (Nelson et al, 2015).

Plasticity Index (%)	Expansion Potential
0–15	Low
0–35	Medium
20–55	High
> 35	Very high

Another important measure of a soils expansive potential is its linear shrinkage which is defined as the decease in one dimension of a soil sample expressed as a percentage of the initial dimension due to reduced water content (Venkatramaiah, 2006).

3.3 Pavement Types

In contemporary road building, there are several factors which must be considered when deciding the most appropriate pavement type. These considerations include traffic volume and loading, availability of materials, subgrade properties and environment. Austroads (AGPT02, 2017) considers road pavements to be divided into the following main categories, each with their own respective subcategories:

- Unbound granular
- Modified and bound granular
- Asphaltic
- Concrete

This research will investigate the uses of each pavement type, including materials required and construction methods.

3.3.1 Unbound Granular Pavements

Unbound granular pavements are those which consist of independent granular particles including crushed rock and gravel layers which are strengthened only by the mechanical interlock of particles due to the aggregate grading. This pavement type is common in the Fraser Coast choice due to its relatively low cost and readily available materials. It is typically surfaced with asphalt or sprayed seal surfacing.

Croney (1998) wrote that an unbound pavement will reduce the vertical compressive strength on the subbase and subgrade by its thickness and level of compaction. In order to bridge a low strength subgrade with an unbound granular pavement requires extra thickness in the subbase or base layer.

Angular and irregular shaped particles (crushed rock) are favoured for unbound pavement construction due to the high level of mechanical interlock which can be achieved. Rounded and Uniformly graded particles tend to create permeable courses and as such allow the ingress of water, effectively compromising the pavement (Maxwell, 2009).

The Department of Transport and Main Roads (2019) have specifications for their own standards of unbound pavement materials which require quarries to possess Transport and Main Roads Quarry Registration, ensuring that the quarry will supply the appropriate material. These materials are categorised by quality into type 1, type 2 and type 3 granular materials with various subtypes.

Type 1 is a high standard, premium granular material, primarily for use in heavy duty unbound pavements with high traffic volumes and compressive loadings. Type 1 material generally has a low clay content and as such lower plasticity index when compared to other materials, meaning that it has low unconfined strength and shouldn’t be constructed under traffic as a wearing course. However, when properly compacted, the type 1 material should provide a dense and durable structure with low permeability.

Type 2 is a standard, high quality granular material, for use in any pavement layer under a diverse range of conditions. Indeed, this is a versatile material which can be constructed under traffic, making it a more attractive option.

Type 3 is a standard material, similar to type 2 however recommended for use in dry climates with low moisture content in soil. Figure 3.6 demonstrates the recommended application of each pavement material.

Average Daily Traffic in Design Lane in Year of Opening (ESA)	Typical Material Type (MRTS05)[1,2,3]		
	Median Annual Rainfall (mm)		
	≥ 800 mm / Year	≥ 500 mm / Year to < 800 mm / Year	< 500 mm / Year
Base			
≥ 1000 to < 3000	1 (HSG)[4]	1 (HSG)[4]	1 (HSG)[4]
≥ 100 to < 1000	2.1	2.1 or 3.1	3.1
10 to < 100	2.1	2.1 or 3.1	3.1
< 10	2.2	2.2 or 3.2	3.2
Upper Subbase			
≥ 1000 to < 3000	2.3	2.3 or 2.4	2.3, 2.4, 3.3 or 3.4
≥ 100 to < 1000	2.3	2.3, 2.4, 3.3 or 3.4	3.3 or 3.4
< 100	2.4	2.4 or 3.4	3.4
Lower Subbase			
All	2.5	2.5 or 3.5	3.5

Figure 3.6: Typical application of standard materials in unbound pavements, Pavement Design Supplement (DTMR, 2018).

3.3.2 Modified and Bound Granular Pavements

Modified and bound granular pavements are those which consist of granular particles which are linked together (bound) by a glue or binder such as cement or bitumen. These pavements do not gain their strength through mechanical interlock like unbound pavements do but rather are strengthened by the layer behaving as a continuous system which absorbs loads across the whole structure. While also known as a stabilised pavement, bound pavements retain their flexible pavement properties subject to the quantity of stabilising agent used. In fact, the only difference between a modified and a bound material is that bound materials contain a much greater quantity of binder (Maxwell, 2009).

The advantage that modified pavements offer is that they have higher tolerances to loadings, improving their modulus without having a significant impact on tensile capacity. This subsequently means that thinner layers are required to achieve the same result as an unbound layer. However, this is offset by the higher unit cost bound materials attract since they are a higher quality material.

In general, the option between unbound and bound granular pavements is typically made by cost, projected traffic volumes and environmental conditions. Since bound materials require less pavement thickness to be effective, they may ultimately be more cost efficient if working in unfavourable conditions with poor subgrade, high water table or where extra thickness isn't achievable due to service locations.

Department of Transport and Main Roads (2018) has identified that due to the nature of modified pavements, they tend to produce larger shrinkage cracks which reflect into overlying layers and surfacing. This impacts the type of surfacing which should be selected and when asphalt is chosen it should be supplemented by a strain alleviating membrane interlayer (SAMI) seal with a polymer modified binder (PMB) to prevent reflective cracking (AGPT04K, 2018).

There are various means of modifying pavements including the addition of cement, bitumen, fly ash or hydrated lime to bind the aggregate particles together and stabilise the pavement. The process of binding a pavement involves mixing, placing and compacting the pavement within a relatively short timeframe to allow it to cure and create a sound working platform. Indeed, modified and bound pavement materials offer a shorter window of when the material is considered workable.

3.3.2.1 Cement

The addition of cement powder to granular materials is a commonly used form of bound pavement in Australia due to the high availability of materials in most locations. In fact, these materials are readily available in the Fraser Coast. The typical cement powders used are general purpose Portland cement (GP) or general purpose blended cement (GB) with GP reaching its optimum strength more rapidly. Lightly bound cemented pavements are considered to be those with a UCS between 1.0 and 2.0 MPa and heavily bound are those with a UCS greater than 2.0MPa with the former being more commonly used in flexible pavements, particularly at local government level (DTMR, 2019).

When constructing cement treated pavements, it is important to ensure that the materials are placed and compacted into layers and to allow those layers to cure before placing any further material. It is recommended by Austroads that a cement treated layer should not exceed thickness of 200mm since any layer greater than this is difficult to guarantee compaction (AGPT02, 2017).

3.3.2.2 Bitumen

Bitumen stabilised pavements generally refer to the use of foamed bitumen to undertake an in-situ stabilisation of the existing pavement. This process involves injecting the existing pavement with foamed bitumen, causing individual particles to become bound by the expansion of the foam. It should be recognised that binding pavement materials in this way requires a much greater amount of skill and ability as opposed to cement bound pavements. Although, it does allow for a longer window of workability. This form of treatment is not commonly used in Fraser Coast due to the availability of labour experienced in this application.

3.4 Pavement Design Methods

There are various methods used across the world to design roads which are suitable for their traffic conditions and environment. In Australia, Austroads is the peak body pertaining to design and maintenance of roads and road assets and as such this section will focus on the publications of Austroads. Before delving into the technicalities of road design, it is important to first understand the structure of a road and how it functions. Figure 3.7 is a sketch of a typical flexible pavement profile.

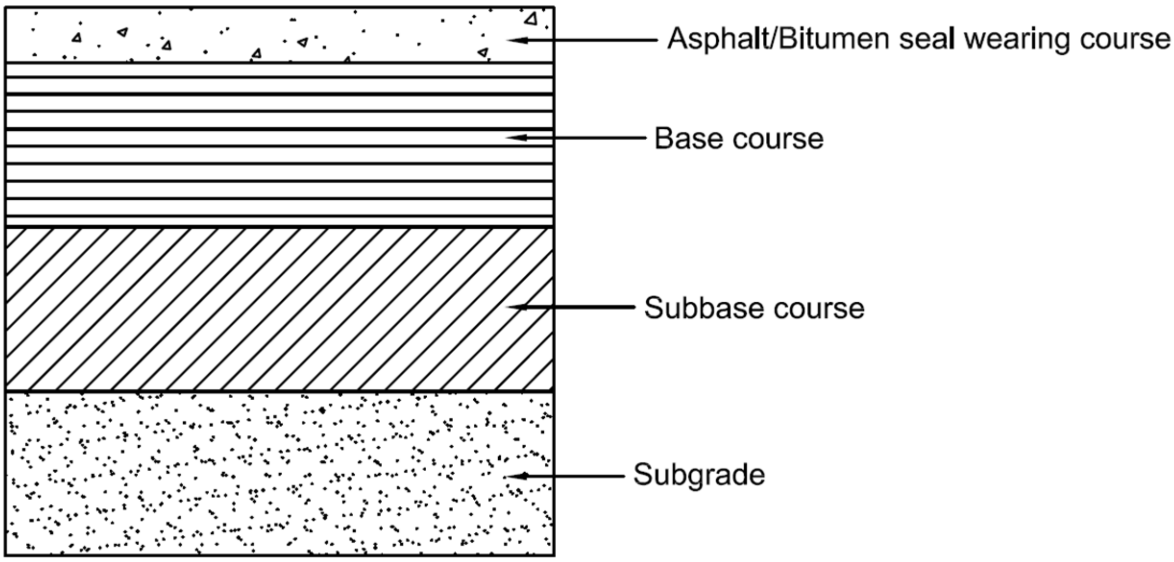

Figure 3.7: Typical flexible pavement profile

There are several inputs which are required in order to produce a pavement design which will be suitable for application. The inputs required, as outlined by Austroads, are the following:

- Design traffic
- Project reliability
- Construction and maintenance considerations
- Environment
- Subgrade evaluation
- Pavement materials

3.4.1 Design Traffic

Design traffic is one of the most important input parameters in the design process and, in fact, it is imperative to ensure its accuracy. The constructed pavement must be of the right dimensions and geometry to accommodate safe vehicle movement at the designated speed while also being strong enough to allow for vehicle flow as required.

The design traffic input is in the form of the design number of equivalent standard axels (DESA) which is derived from the number of vehicles and heavy vehicles. It can be expected that over the design life of a road, the traffic volume will experience changes and is likely to increase. This can be modelled using a standard compound growth formula where the annual growth rate is known or can be assumed.

$$CGF = \frac{(1 + 0.01R)^P - 1}{0.01R} for\ R > 0 \tag{3.1}$$

Where

$CGF =$ Cumulative growth factor

$R =$ Annual growth rate (%)

$P =$ Design period (years)

This CGF can then be used to determine the projected AADT and heavy vehicle traffic of the road at the end of the design life. This is imperative to ensuring that the road is adequately designed and constructed to cater for future growth.

$$N_{DT} = (Opening\ HV\ per\ day) \times 365 \times CGF \times N_{HVAG} \tag{3.2}$$

$N_{DT} =$ Cumulative number of heavy vehicle axle groups over design period.

N_{HVAG} = Average number of axle groups per heavy vehicle

$$DESA = \frac{ESA}{HVAG} \times N_{DT} \tag{3.3}$$

$ESA/HVAG$ = Average number of ESA per heavy vehicle axle group.

In most cases traffic data is obtained using traffic counters placed on the road to detect the volume and type of axles which pass over them. However, in regional areas such as the Fraser Coast, where up to date traffic count data is not available for every road, a traffic count is derived from available data from nearby roads and scaled to consider the population the road may serve.

3.4.2 Project Reliability

Project reliability encompasses an assessment of how the constructed pavement will perform when evaluated against its design life criteria. Project reliability takes into consideration that there are potentially errors in the design and quality issues with materials and constructability. It effectively means the probability of the constructed pavement outlasting its design traffic assuming that it is constructed in accordance with the standard (AGPT02, 2017. Table 3.2 demonstrates the typical project reliability levels of different road classes.

Table 3.2: Typical Project Reliability Levels (AGPT02, 2017).

Road Class	Project Reliability %
Freeway	95-97.5
Highway: lane AADT$>$ 2000	90-97.5
Highway: lane AADT$\leq$ 2000	85-95
Main road: lane AADT$>$ 500	85-95
Other roads: lane AADT $\leq$ 500	80-90

3.4.3 Construction and Maintenance Considerations

The longevity of any pavement is determined not only by the quality of the design and materials used but also the quality of the construction. This includes level of compaction, curing of cement treated materials, the type of equipment and the performance of subsurface drainage.

A typical method for road construction is known as boxed construction whereby the material is excavated in boxed sections rather than full width. When undertaking boxed construction, care must be taken to avoid ingress of water into the exposed subgrade which can easily occur since there is no adequate drainage at the base of excavation. In the pavement design, consideration should also be given to the provision of longitudinal subsurface drainage which captures water filtered to subgrade level and transports it out of the subgrade material to prevent the weakening of the pavement.

When considering the impact that construction may have on traffic and the community, staged construction may be employed to reduce that impact. Staged construction involves undertaking the project in stages, either due to financial constraints or to allow for different traffic movements. It is common practice in road reconstruction to seal the surface of the newly constructed road at one time when all stages are complete. In this circumstance, it is important to be aware of the environmental conditions including weather as well as having an understanding of the pavement materials in use as rainwater may degrade the new pavement.

When considering a pavement profile, it is important to analyse the life cycle costs including any maintenance requirements. Some pavements may require more regular maintenance than others which when considered against the construction cost, may indicate that a particular profile is not economically feasible.

3.4.4 Environment

When constructing a road it is important to be aware of the natural environment including the nature of the existing earth materials. When assessing a location for a new or upgraded road, local rainfall data is important to consider constructability and pavement requirements for a new road. Austroads suggests that moisture ingress into pavements not only occurs through the surface but also through seepage of the underlying ground materials. This is particularly important in the Fraser Coast due to the high amount of rainfall that the region receives, highlighting the need for subsurface drainage structures. Figure 3.8 is an illustration of the movements of moisture within road pavements.

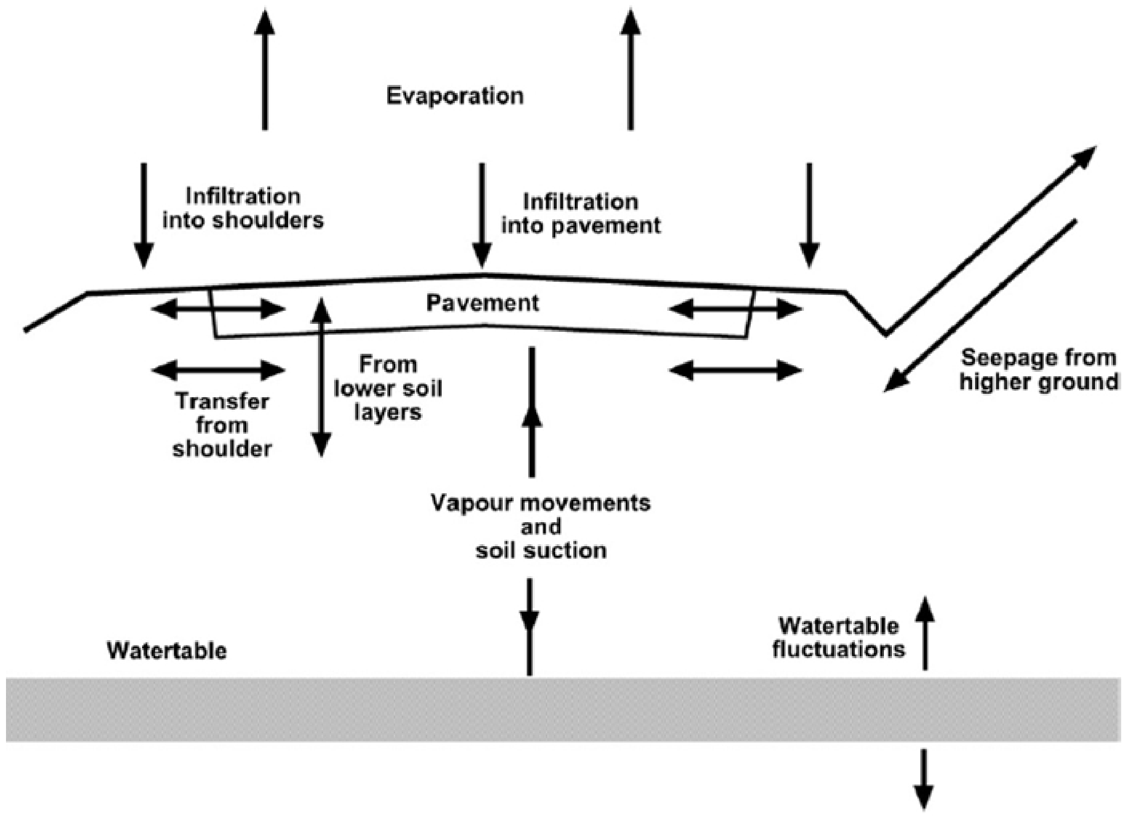

Figure 3.8: Moisture movements in road pavements (AGPT02, 2017).

It is imperative to understand these moisture movements when designing a road pavement to ensure that the existing conditions do not allow for the degradation of the new pavement. Table 3.3 demonstrates the affect that moisture has on various materials.

Table 3.3: Changes in materials due to moisture

Material	Affect Due to Moisture
Sand	Little change in volume and strength
Silty soil	Little change in volume but large change in strength
Clay	Large variations in volume and large changes in strength

As such, it can be seen that depending on the subgrade material type, there may be large variances in strength and volume due to the ingress of moisture, leading to failures in the pavement layers. This information will be of significant value when evaluating subgrade conditions for pavement reconstruction works.

3.4.5 Subgrade Evaluation

One of the most important aspects in road pavement design is the composition and condition of the subgrade which governs pavement thickness, materials and ultimately performance. The first step of any road construction project is the commission of a geotechnical report to investigate the existing road pavement features and evaluate the subgrade material by determining a CBR value. There are various accepted methods of determining the subgrade CBR value including laboratory and field testing methods. The laboratory methods are considered to be more accurate, however they require more time to undertake. When conducting a lab test, the CBR value can be determined at the desirable moisture content meaning that in high rainfall areas, a soaked CBR value is favourable while in dry arid environments, an un-soaked CBR value is required (AGPT02, 2017). Due to the high rainfall in the Fraser coast, FCRC require soaked CBR tests.

The dynamic cone penetrometer test (DCP) is the most commonly used form of insitu CBR testing and is often used to confirm the results of the lab test during construction. The determined CBR value is known as a presumptive value as it is determined by the relationship between CBR and penetration into the material. Figure 3.9 is the graph used to determine the presumptive CBR value.

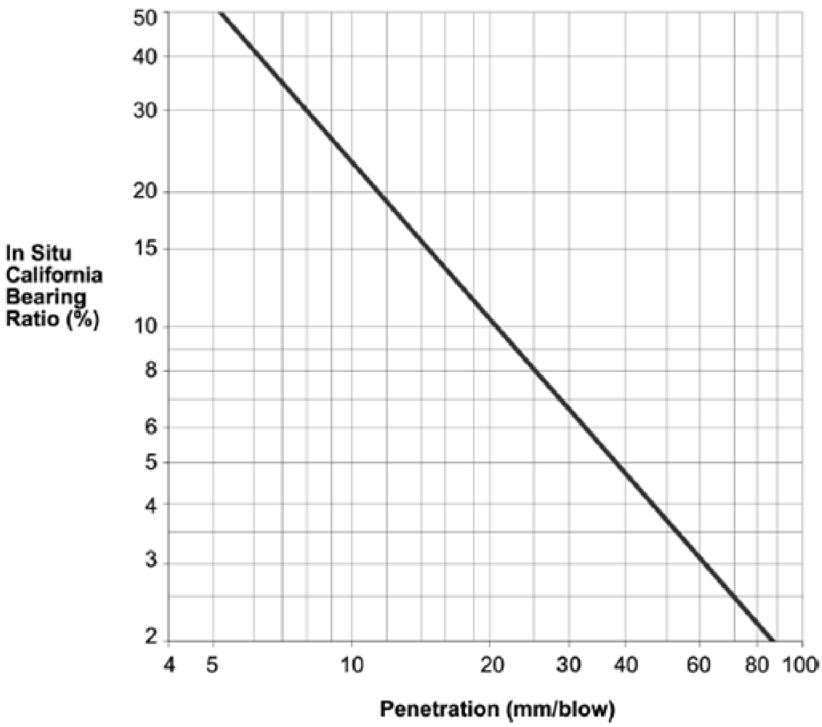

Figure 3.9: Relationship between DCP and CBR (AGPT02, 2017)

3.4.6 Empirical Design Method

The empirical design method is a well established pavement design method used across the world and is based upon the relationship between design inputs and pavement failures which are determined through experience (AASHTO, 1993). The AASHTO in the United States was one of the pioneering bodies of the empirical design method dating back to the mid 20^{th} century. In 1993, the AASHTO published their guide for design of pavement structures, detailing historical methods and techniques of pavement design which ultimately came to be known as the emperical method. The empirical design method is used only for the design of granular pavements with thin bituminous surfacing and as such has limitations in real world applications. However, the empirical design method is commonly used in many applications, particularly by local authorities with limited resources and available materials as it is a relatively simple design method.

The basic principle of the empirical design method is that the composition of the new pavement structure is constructed to provide sufficient cover to the subgrade and each subsequent layer. Furthermore, O'Flaherty suggested that the basis of the empirical design method was such that the thickness of each course should prevent the overstressing and failure of underlying layers (O'Flaterhy, 2015). To determine the appropriate layer depths, the subgrade CBR and design traffic are the only required inputs. Austroads has developed two charts which represent the relationship between pavement thicknesses and the inputs in order to determine the most suitable granular pavements. Figure 3.10 is for heavily trafficked granular pavements and Figure 3.11 is for lightly trafficked pavements. Austroads also recommends that when constructing pavement layers, all layers must have a CBR value greater than the layer that precedes it. When constructing the base layer, this method assumes that a material with minimum CBR$\geq$ 80% will be used with at least 100mm thickness.

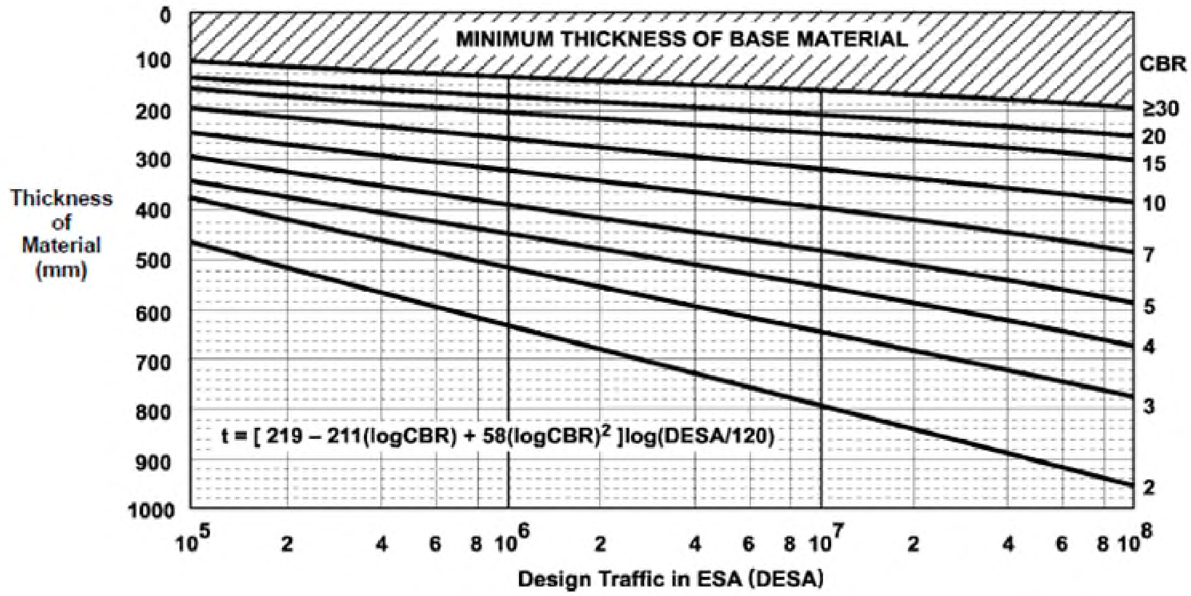

Figure 3.10: Design chart for granular pavements with thin bituminous surfacing (AGPT02 2017)

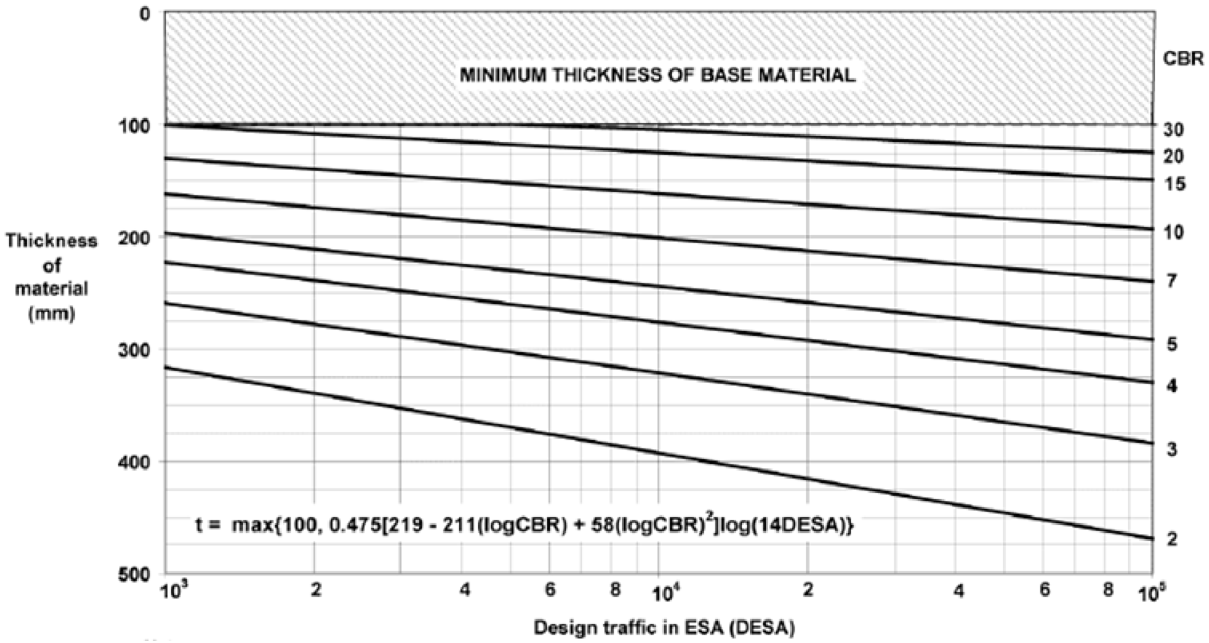

Figure 3.11: Design chart for lightly trafficked granular pavements with thin bituminous surfacing (AGPT02, 2017)

3.4.7 Mechanistic Design Method

Building upon the empirical method, the mechanistic method, as the name suggests allows the pavement designer to examine the mechanics of the proposed pavement through stress and strain analysis. As such, this method has become increasingly prevalent due to the ubiquitous presence of computer systems to aid with the complex analysis. Once the mechanics of the structure are analysed, the selected pavement can be modelled to predict the fatigue conditions including how and when the road will fail (Maxwell, 2009). This is a very useful tool in modern road design.

The design procedure is based around structural analysis where the pavement is modelled as a multi-layer structure subject to loading conditions. Subsequently, empirical design equations are used to determine the selected pavement's conditions of failure. In the instance that the selected pavement design does not meet the project requirements, a revised pavement design shall be modelled. As such, this is an iterative process where trial and error is used to find the most suitable pavement design.

CIRLCY is the most commonly used pavement design software program in Australia and is endorsed by Austroads as an acceptable pavement design tool. In fact, CIRCLY has been part of the Austroads Pavement Design Guide since 1987 (Pavement-Science, 2020) and it models the pavement as a linear elastic model to determine the internal stresses and strains. Although it is the preferred design method, CIRLCY has a number of limitations and assumptions as outlined by Austroads (AGPT02, 2017).

1. P*avement materials are considered to be homogeneous, elastic and isotropic (except for unbound granular materials and subgrades*
2. *Responses resulting from each axle within each axle group and applied load level within the design traffic load distribution (TLD) are determined.*
3. *Response to load is calculated using a linear elastic model, such as the computer programs AustPADS (Austroads Pavement Analysis Design Software) and CIRCLY. The program must be able to model anisotropic materials.*
4. *The critical responses assessed for pavement and subgrade materials are:*
   a. asphalt – horizontal tensile strain at bottom of layer
   b. cemented material/lean-mix concrete – horizontal tensile strain at bottom of layer
   c. subgrade, selected subgrade and lime-stabilised subgrade material – vertical compressive strain at the top of the layer.
   Note, responses in unbound granular materials are not considered by the design model.
5. *Responses are determined under a single-tyred single axle applying a load of 53 kN and a dual tyred single axle applying a load of 80 kN. These responses are linearly scaled with load to determine the responses resulting from other axle loads within the design TLD*

6. *For flexible pavements, the critical responses within the pavement occur either along the vertical axis directly below the tyre of the single tyre group and the inner-most tyre of the dual tyre group or along the vertical axis located symmetrically between a pair of dual tyres (Figure 8.2).*
7. *Single-tyred axle loading is represented by two uniformly-loaded circular areas of equal area (radius 102.4 mm) separated by a centre-to-centre distance of 2130 mm as illustrated in Figure 8.2. The contact stress is assumed to be uniform over the loaded area and, for the purpose of design, is taken to be 800 kPa. The contact stress is related to the air pressure in the tyre in-service which for highway traffic is assumed to be in the range 500–1000 kPa.*
8. *Dual tyred axle loading is represented by four uniformly-loaded circular areas of equal area (radius 92.1 mm) separated by centre-to-centre distances of 330 mm, 1470 mm, and 330 mm respectively as illustrated in Figure 8.2. The contact stress is assumed to be uniform over the loaded area and, for the purpose of design, is taken to be 750 kPa. The contact stress is related to the air pressure in the tyre inservice which for highway traffic is assumed to be in the range 500–1000 kPa.*
9. *The dual tyred axle of the geometry shown in Figure 8.2, applying a 80 kN load and with circular tyre contact stress of 750 kPa is termed the Standard Axle*
10. *Some variations to the above may be appropriate for other than normal axle types and loadings; for example, where sharp turning movements or acceleration or braking occur. A model which more closely corresponds to the actual axle configuration and loading should be adopted in such cases. However, this is rarely undertaken for most pavement design situations and there is little case study experience to relate the calculated pavement responses to pavement performance.*
11. *For some projects, the mechanistic-empirical modelling may indicate that both a thin (< 50 mm) and thick asphalt surfaced pavement can be adopted. Caution is advised in adopting the thin asphalt surfaced pavement option because the dominant damage types are not necessarily those addressed by the design model and as a consequence mechanistic-empirical modelling of asphalt layers less than 40 mm thick is less certain than for thicker asphalt layers*

Austroads Guide to Pavement Technology Part 2 (2017) outlines a detailed design procedure for different pavement materials and selected subgrades to determine if a trial pavement is appropriate for the given project requirements. It should be recognised that in the mechanistic method there is no procedure to accurately determine the failure mode of unbound granular materials. As such, the elastic properties of unbound granular materials is found using the same procedure as subgrade.

Procedure for Subgrade

The procedure for the elastic characterisation of subgrade materials involves dividing the thickness of each selected subgrade or stabilised subgrade into five (5) equally thick layers. The vertical modulus of the top layer can then be found by the following equation:

$$E_{V\ top\ sublayer} = E_{V\ underlying\ material} \times 2^{\frac{thickness\ of\ each\ selected\ layer}{150}}$$

With this, the ratio of moduli of adjacent sublayers can be found using the following equation:

$$R = \left[\frac{E_{V\ material\ in\ top\ sublayer}}{E_{V\ underlying\ layer}}\right]^{\frac{1}{5}}$$

Procedure for Asphalt

The allowable number axle repetitions (N) can be determined by relating the maximum horizontal tensile strain developed at the base of these materials for a single axle group(i).

$$N_{ij} = \frac{1}{n} \times \frac{SF}{RF} \times \left[\frac{6918(0.85V_b + 1.08)}{E^{0.36}\mu\varepsilon_{ij}}\right]$$

$N_{ij} = number\ allowable\ repetitions$

$n = number\ of\ inidividual\ axles$

$\mu\varepsilon_{ij} = load - induced\ tensile\ strain\ at\ the\ base\ of\ the\ aspahlt$

$V_b = \%\ by\ folume\ of\ bitumen\ in\ asphalt$

$E = Asphalt\ modulus\ (MPa)$

$SF = Shift\ factor\ between\ lab\ and\ in - service\ fatigure\ life$

$RF = Reliability\ Factor\ for\ asphalt\ fatigue\ (table\ 3.4)$

Table 3.4: Reliability for Asphalt (AGPT02, 2017)

Desired Project Reliability for Asphalt				
50%	80%	85%	90%	97.5%
1.0	2.4	3.0	6.0	9.0

Procedure for Cemented Materials

$$N_{ij} = \frac{1}{n} \times RF \times \left(\frac{K}{\mu\varepsilon_{ij}}\right)^{12}$$

$N_{ij} = number\ allowable\ repetitions$

$n = number\ of\ inidividual\ axles$

$\mu\varepsilon_{ij} = load - induced\ tensile\ strain\ at\ the\ base\ of\ the\ asphalt$

$RF = Reliability\ Factor\ for\ asphalt\ fatigue$

$K = presumtive\ consant\ (table\ 3.5)$

Table 3.5: Reliability for Cemented Materials (AGPT02, 2017)

Desired Project Reliability for Cemented Materials				
50%	80%	85%	90%	97.5%
25	4.7	3.3	2.0	0.5

3.5 Pavement Evaluation Methods

When considering the projected life and analysing the performance of an existing road pavement, it is important to accurately evaluate the existing profile to identify failures and modes of distress. This is a critical step in determining the most suitable treatment options and also predicting the remaining service life of the asset. There are various means of evaluating a pavement including physical on-site investigation and remote investigation such as falling weight deflectometer (FWD) and laser profilometer data. For the purpose of this research project, this section will focus on non-destructive means of pavement evaluation.

Austroads Guide to Pavement Technology Part 5: Pavement Evaluation (2019), outlines the importance of obtaining a range of data to accurately assess the existing pavement condition including:

- Historical Data
    - Original Pavement Design
    - Materials Data
    - Construction Details
- Field Survey
    - Visual Condition Data
    - Environmental Data

3.5.1 Failure Modes

Flexible pavements exhibit a large variety of failure modes including deformation, cracking and surface distress which can be identified through non-destructive means. The causes of distress are varied and can include climatic, loading and foundational issues which may not have been accurately assessed at the time of design or construction. Deformation is typically representative of an underlying pavement failure often caused by moisture ingress through a cracked or pervious surface. Surface distress modes on the other hand and most commonly caused by issues with the surface treatment such as incorrect binder or aggregate quantities and don’t indicate that there is a problem with the underlying pavement (Maxwell, 2009). Figure 3.12 is an illustration of the deformations which flexible pavements may undergo.

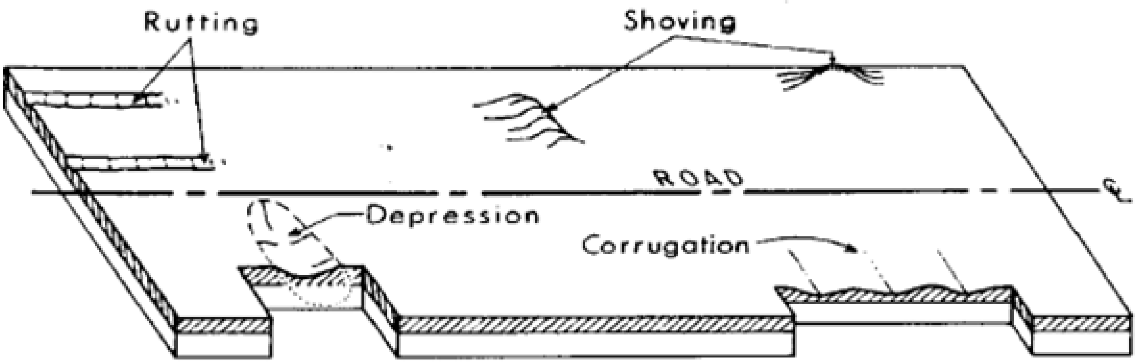

Figure 3.12: Deformation of Flexible Pavements (AGPT05, 2019)

Rutting is the deformation of pavement in the wheel path caused by repetitive wheel loading on the pavement surface, manifesting in longitudinal depressions. The Australian Asphalt Pavement Association (AAPA) suggested that a well-designed pavement should rut at a rate of approximately 1mm in depth per year and should be resurfaced after 20 years. If the pavement is rutting at a higher rate then it is evidence of a pavement issue such as poor construction or higher than estimated design traffic. When a rut has exceeded 20mm in depth, it is no longer providing adequate skid resistance in wet conditions, posing a serviceability issue. Furthermore, if a rut continues past a depth of 20mm without being addressed, it may impact the effective depth of the base and subbase, reducing the pavement performance (AAPA, 2019). To determine the rut depth it is common practice to place 1.2m long straight edge transversely across the rut path and measure the maximum vertical displacement (DTMR, 2019). Austroads Guide to Asset Management Part 5C: Rutting, suggests that when analysing rut depths, a measurement should be taken at 100m intervals and then categorised based on their extents. Furthermore, while rut depths can be measured in the inner and outer wheel paths, the larger of the two values, known as lane rutting, is used to compare and consider overall road condition (AGAM5C, 2007).

Pavement depressions are known as irregular depressions or bulges in the pavement surface and may be caused by moisture ingress, subgrade movement or poorly compacted base material. This issue can be repaired by a resurfacing treatment however it is likely to reoccur since it is a structural deformation and not a surface issue. Hence, it is more beneficial to do an isolated pavement repair or in-situ stabilisation of the existing material.

Shoving can be identified as horizontal deformation of the road surface, most commonly in high shear stress zones and can have several causes, making it a complicated pavement failure to address. The main causes include inadequate adhesion between the asphalt or spray sealed surface, poorly compacted pavement material and thickness as well as moisture ingress.

Corrugations in road pavements can be identified as traverse undulations in the surface at wavelengths of 0.3 to 2.0m. This failure is typically found in spray sealed roads however it is not exclusive and can be also be found in unsealed or thinly surfaced asphalt roads. The cause is inadequate material quality and poor bonding between the surface and the base which fails to resist heavy loading and high shear stress. While this can be repaired with an asphalt overlay, it is recommended to address the issues in the underlying pavement with a reconstruction or isolated pavement repairs (DTMR, 2019).

In addition to deformation defects, flexible pavements also undergo various surface distress which can be identified through visual inspection. Figure 3.13 is an illustration of the types of surface distress a flexible pavement may exhibit.

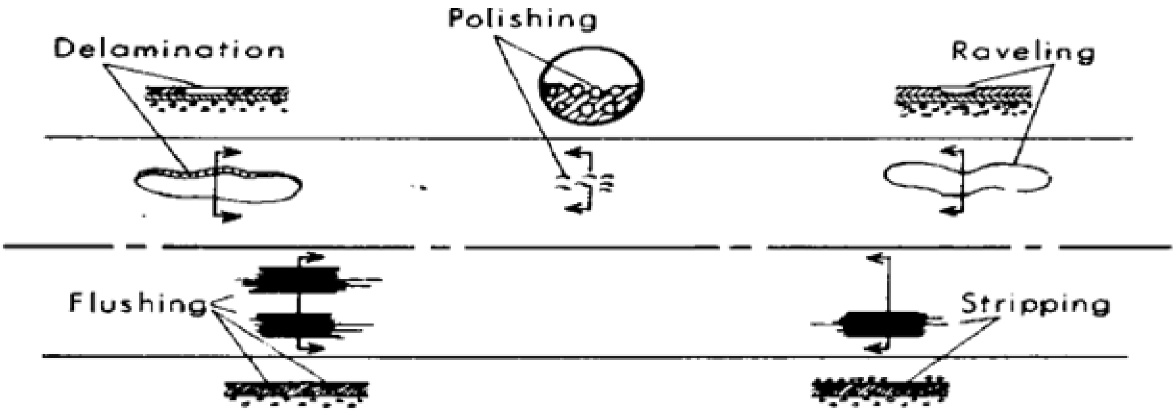

Figure 3.13: Surface distress in flexible pavements (AGPT05, 2019)

These types of surface defects are typically representative of issues with the surfacing (bitumen and asphalt) which may significantly reduce the life of the pavement if not attended to. Delamination is the process whereby the wearing course delaminated from the underlying pavement and is due to the bitumen not adhering to the lower layer. This may be due to poor application of prime, weak base course or poor surface preparation. Stripping can occur in bitumen and asphaltic wearing courses and is the loss of aggregate from a spray sealed surface and loss of bitumen from an asphaltic surface respectively. This is often caused by inadequate binder content for the traffic volume.

Ravelling typically occurs in asphaltic wearing courses and is the progressive loss of both binder and aggregate from the surface. This is caused due to oxidisation and hardening of the binder content, leading to brittle localised failures. On the other hand, flushing is known as excess binder on the surface of the wearing course, often in the wheel paths. This is due to excessive amounts of binder being used, poor penetration into the pavement layer or inadequate traffic volume data.

A common method of deformation monitoring and condition testing is the use of a network survey vehicle with an attached laser profilometer, similar to the one in Figure 3.14. This vehicle is used to traverse road networks and has the ability to identify surface defects such as crocodile cracking, rutting, flushing and roughness. The roughness value is provided in terms of the International Roughness Index which is a mathematical model of a motel vehicle expressed as the simulated displacement of suspension in metres measured per kilometre (m/km) (AGAM-T001,2016).

Figure 3.14: NSV with laser profilometer (AARB, 2020)

3.6 Subgrade Treatment Options for Fraser Coast

The Fraser Coast Region Queensland generally has very low CBR subgrade material across the region, posing the difficult task of constructing and maintaining public infrastructure. Determining the composition and characteristics of a road's subgrade is the single most critical element in the design of any road pavement as the constructed road must be adequately supported by the natural material beneath. Indeed, this was explained by Maxwell who wrote that the subgrade material is the foundation on which a road is constructed and must be carefully considered for the constructed pavement to have any chance of reaching its intended life (Maxwell, 2009).

There are various treatments and remedies available to improve subgrade conditions which is particularly useful on plastic subgrades as found in the Fraser Coast. The main characteristics which require improvement include:

- Strength – Silty clay soils often have low CBR values and require improvement to support the pavement structure.

- Moisture Content - Plastic soils generally have good bearing capacities when at low moisture content however this capacity is significantly reduced when moisture is introduced.

3.6.1 Subgrade Replacement

Subgrade replacement is a common treatment used to improve subgrade conditions which involves removing and replacing the natural material which higher quality rock or road base. This is a useful technique as it offers a more suitable platform to construct the pavement structure onto however it does have some limitations. In some instances, removing the natural subgrade may not expose any better material and in fact may expose poorer quality material, further hindering the construction. As such, it is important to investigate this by undertaking a DCP test to determine if there is higher quality material at greater depths (Maxwell, 2009). This method of subgrade improvement is also labour intensive and extends the time required for the project as the new subgrade material must be properly placed and compacted.

3.6.2 Geotextiles

Geotextiles are a manufactured material used to improve pavement structures and, in some cases, reduce pavement depths. The have many uses in the roads industry including separation, filtration, drainage, and reinforcement. Croney (1998) suggested that the use of geotextiles can be very effective in reducing deformation and strengthening the pavement structure. Table 3.15 shows a comparison of deformation noted with and without a woven geotextile separation layer between subgrade and granular subbase.

Table 3.6: Pavement deformation comparison of geofabric (Croney, 2009).

Number of passes with truck	Permanent deformation at the surface (mm)	
	without fabric	With fabric
50	28	20
100	37	25
200	47	29
300	53	32

There is a large range of geotextile products available on the market, each with different applications and uses. One particularly useful kind are geogrids, a polymer biaxial or triaxial grid to allow for interlocking of aggregates. This work by placing the grid, often at subgrade level, placing and compacting the granular subbase material and then the aggregated interlocking to form a strengthened platform for the pavement. These products have proven to be very useful in reducing the effective depth of pavements and at relatively low cost. Geocomposites are the combination of two forms of geotextile, often a fabric and a grid, to create a very versatile product.

3.7 Road building materials available in the Fraser Coast

Regional areas often have difficulty sourcing readily available materials for a variety of tasks which are also high quality and at a reasonable cost. Indeed, typically the cost of materials increases the further a location is from a capital city due to transport costs. Fortunately, the Fraser Coast boasts several reputable quarries, each of which produce quality granular material for road construction activities. The most commonly used materials are the DTMR standard type 2 granular road bases which have the ability to be treated at the plant to be used at bound pavement materials. Furthermore, crushed and coarse rock, favoured for subgrade replacement is readily available.

Chapter 4 - Research Design and Methodology

4.1 Aims and Objectives

This research project sought to investigate the current road reconstruction methods at the Fraser Coast Regional Council and identify the optimum pavement configuration given the geological conditions and materials available in the region. This was done by investigating the current pavement reconstruction practices at the Fraser Coast Regional Council and researching current Australian and international methods. The research phase also includes an investigation into the geology of the Fraser Coast Region and a study of the availability and quality of materials available in the region.

In undertaking this research, up to 8 roads across the region were identified which have been reconstructed within the last 10 years. Since this study focuses on the main population areas of Hervey Bay and Maryborough, the selection of roads should be split evenly between the two locations. It was aimed that by investigating this number of roads, it will give an accurate representation of the effectiveness of road reconstruction methods used in the region.

4.2 Consequential Effects and their Implications

There is an array of potential effects and implications associated with this project which must be identified prior to commencement.

4.2.1 Sustainability Issues

This research project was undertaken in accordance with the Engineers Australia Sustainability Policy (2014) in order to maintain a high level of accountability to sustain natural resources and social capital. This is done with the appreciation that engineering outcomes must ensure a higher standard of living and pristine natural environment for future generations. The ways in which the sustainability policy will be adhered to include the following:

- Applying sound knowledge, skills and engineering principles to achieve desirable outcomes which will promote sustainability and encourage the retention of resources for future generations.

- Maintain a sound understanding of sustainability principles and keep up to date with any updates from Engineers Australia regarding sustainability practices in engineering.

- Take an innovative approach to problem solving while thinking holistically and considering the wider implications of project work to ensure that there is a sustainability benefit. It is important to recognise the environmental, societal and economic impacts and risks throughout the research project.

4.2.2 Safety Issues and Risk Assessment

Due to the nature of this project work, safety is of paramount importance and all work shall be carried out in accordance with the Work Health and Safety Act Queensland, 2011. As site visits are an integral part of this project, the ways in which this guideline will be adhered to include the following:

- Wearing appropriate PPE;
  - Hi-visibility vest
  - Hat and sunscreen
  - Steel capped boots in accordance with AS2110.3
- Operation of Vehicle to travel to site
  - Possess class ‘C’ driver’s license
  - Adhere to road rules and regulations

A risk assessment of potential hazards that may arise throughout the project has been conducted and is attached in the appendix.

4.2.3 Ethical Issues

The Engineers Australia Code of Ethics outlines the behaviours and values which are expected of an engineer in contemporary Australia. This code and its principles are essential to ensure that engineers have a framework for decision making which will allow for outcomes which are consistent with upholding the reputation of engineering (EA, 2019). The four pillars of ethics, as outlined by Engineers Australia, supplemented by how they will be demonstrated by this project are as follows;

1. *Demonstrate Integrity*

   This research project will demonstrate integrity by fairly and critically assessing various sources as part of a literature search to determine various means of road construction which may be applicable to the Fraser Coast region. When utilising various sources in this research project, credit will be given where due to recognise that a third party’s information is being used. Furthermore, throughout the project, fair and honest assessments will be made to ensure the accuracy of the data and results. This is critically important as the final outcome will be presented to the Fraser Coast Regional Council as advice on their current practices.

2. *Practice Competently*

   This project will be conducted in a way which demonstrates a high level of professionalism and diligence in order to achieve an outcome which is of a high standard. It is aimed that throughout the research and investigation process, a range of skills and knowledge will be gained which will be useful in contributing to the wider engineering community through the engineering profession. Additionally, all decision and actions taken throughout the project will be made only when sufficient information and knowledge has been obtained.

3. *Exercise Leadership*

   Throughout this project, all activities will be conducted in a manner which will uphold the reputation of engineering and encourage trust in the profession. All stakeholders will be honestly and effectively communicated with to ensure clarity and transparency.

4. *Promote Sustainability*

   The purpose of this project is to identify the current road reconstruction methods used in the Fraser Coast region, offer what improvements can be made and also identify the most effective pavement types for the region in terms of cost and constructability. This, at its core, is an effort which is made for the betterment of the region to ensure that public money is spent in the most effective manner to achieve the best long term outcome. This is done with the needs of future generations in mind as any work which is undertaken today has economic, environmental and social consequences for the future.

4.3 Project Limitations

It is recognised that there are various limitations to this research project due to the scope of the work. The primary objective is to identify the most effective pavement profile for road reconstructions in the Fraser Coast by analysing data of up to 8 roads which have been reconstructed within the last 10 years. As such, there is a heavy reliance on the accuracy of the data and the assumption that any major changes to the project have been captured in the project budget and as constructed data. Furthermore, the data available may not be reliable if it is not current. This is primarily only a concern when considering the road condition data available as the data available from FCRC is from 2017 which does not provide an accurate understanding of the current road condition.

Due to the availability of materials and relevant skill in the region, there is a limited range of different pavement profiles and methods used, in fact some that are selected may be variations of the same type of pavement. Hence, it should be recognised that this research is limited to the Fraser Coast region and must not be considered an all-encompassing evaluation of pavement reconstruction in general.

4.4 Project Methodology

This section will outline the methodology to be used in this project to obtain the data required to make an accurate assessment of the most effective pavement for road reconstructions in the Fraser Coast region. The methodology is listed below:

1. *Research the geological conditions of the Fraser Coast Region, Queensland.*

   This research was undertaken to determine the underlying geological conditions present in the Fraser Coast region, with a primary focus on the main populated areas of Hervey Bay and Maryborough. This was done by reviewing a range of reports including those published by the Geological Society of Australia in conjunction with various geological maps including the Queensland Globe, published by the Queensland Government.

2. *Research road pavement reconstruction methods used at Fraser Coast Regional Council and across Australia.*

   The research process was undertaken to obtain resources including publications, books, reports, articles and dissertations to obtain accurate information. In order to investigate current Australian pavement practices, a thorough review of the Austroads design manuals and supplementary standards published by Queensland Department of Transport and Main Roads was conducted.

3. *Identify up to 8 roads which have been reconstructed by the Fraser Coast Regional Council within the last 10 years to conduct an evaluation of pavement profiles and construction methods.*

The details and investigation of each identified road are outlined in Chapter 5, Site Selection. The reasoning for selecting up to 8 roads is to ensure a reliable spread of data can be obtained and hence the selected roads are evenly split between the towns of Hervey Bay and Maryborough.

4. *Obtain and review construction data for each road including construction drawings, as constructed data, geotechnical information, project costs, project methodology and any other data which may be relevant.*

All data relevant to the construction of the particular roads which are identified has been obtained to allow for an evaluation of the different pavement profiles. This data was used to a conduct cost benefit analysis to determine which pavements offer the most benefit to the community over their life cycle. Included in this data is the road condition data provided to the Fraser Coast Regional Council by the Australian Road Research Board which conducts condition evaluations on the entire local government road network. It must be recognised, however, that the latest available data is from 2017 and as such must be compared with physical site inspection data to gain a proper understanding of the pavement's performance.

5. *Evaluate existing pavement condition through non-destructive means and conduct a comparison of the constructed pavement profiles.*

The existing pavement condition of each road was evaluated in accordance with the procedures outlined in Austroads Guide to Pavement Technology Part 5: Pavement Evaluation. In order to consider the performance of the pavement, the 2017 laser profilometer condition data was used as a benchmark against physical rut depth measurements taken during the site visits. The 2017 data coordinates were plotted to KML to ensure that the ruts were measured in the same location as the 2017 data was taken. Design checks were undertaken to confirm the validity of the pavement design for the given input parameters (where available). The As constructed pavement profiles were then compared to consider cost implications as well determine the effectiveness of the pavement designs.

6. *Propose alternative pavement designs and evaluate their performance using CIRCLY*

Following the evaluation of current reconstruction methods in the Fraser Coast, 3 alternative pavement designs were chosen to consider their effectiveness in the Fraser Coast Region. The traffic data and geotechnical information revealed in chapter 5 was used as a guide to model the profiles using CIRCLY for low order and high order road scenarios.

7. *Conduct life cycle cost analysis (LCCA) of the alternative pavement profiles including estimates of construction and life-cycle costs.*

A life cycle cost analysis was conducted of the alternative pavement profiles to consider the most suitable for use in the Fraser Coast. This was done by considering their estimated initial cost based on the layer thicknesses determined in CIRCLY, estimating the maintenance schedule costs and using the present worth of costs (PWOC) method to determine the most cost effective solution. All costs were determine using rates from FCRC contracts.

8. *Consider the outcome of items 4 and 7 to make conclusions on the most effective pavement profile for use in road reconstructions in the Fraser Coast.*

The outcomes of items 4 and items 7 were compared and considered in order to make a conclusion on the most effective pavement profiles to use in road reconstruction projects in the Fraser Coast. These recommendations are made with the intention that the suggested profiles will allow for the road network to be most adequately serviced and maintained into the future due to the economic benefit which can be achieved.

Chapter 5 - Site Selection

As a means of providing an accurate and thorough representation of the geological conditions of the Fraser Coast, 8 sites were selected, 4 in Hervey Bay and 4 in Maryborough. These sites were selected after consultation with FCRC staff to identify sites which may be suitable for investigation. When identifying the locations, each site was assessed on the following criteria:

- Date of construction and availability of adequate data
- Location
- Traffic volumes

It was important when considering any site that the pavement profiles vary in order to provide a more encompassing evaluation of pavement profiles and construction techniques. As such, this is expected to form a sound basis on which to conduct a life-cycle analysis to determine the most suitable options for pavement reconstruction in the Fraser Coast.

After obtaining local knowledge to find appropriate sites to investigate, a physical site visit was conducted to examine the condition of the pavement and identify any extraneous factors which may influence the performance of the pavement. Site visit records of each selected site can be found attached in the appendix.

5.1 Data Collection

To ensure an accurate evaluation could be undertaken, it was necessary to obtain a range of historical data from the Fraser Coast Regional Council for each site. This data includes:

- Any original condition data and photos
- Geotechnical investigation data
- Design plans and as constructed data
- Project costs

Further to obtaining this construction data, an evaluation of the existing pavement was undertaken as a combination of visual inspection and also analysis of condition testing data obtained from FCRC. Traffic count data was also obtained from FCRC to estimate the accuracy of traffic design assumptions.

Construction data including methodologies was also sourced from FCRC's records to provide an improved understanding of how each project was constructed and how it may be improved. The range of construction data required includes:

- Construction programme
- Traffic allowances and conditions

5.2 Main St Hervey Bay

Main St Hervey Bay was identified in 2000 as part of FCRC's future works programme as in need of reconstruction to meet future traffic demands due to the growing population. Main St is an urban arterial road and has a southbound orientation from the central business district of Pialba, leading to Booral Road, a major connection to Maryborough. Main St also has several major roads adjoining it to connect to the surrounding suburbs of Hervey Bay.

Records obtained from FCRC indicate that the existing road pavement exhibited extensive pavement failures, cracking and patching with no residual life. The existing formation is shown in figure 5.1.

Figure 5.1: Main Street Hervey Bay – Existing Formation

The existing road structure did not contain kerb and channel and stormwater drainage structures for most of its length and relied on poorly formed table drains to capture water. The major gullies on Main St had minimal cross drainage, not capable of carrying the Q50 flood event they were intended to. This is likely to be the primary cause of failure as moisture would have been permitted to enter the pavement.

In 2000, the then Hervey Bay City Council commissioned a geotechnical investigation of Main St and a total of 13 bore holes were drilled with moisture contents and DCP's taken at each location. Soaked CBR's were taken of the subgrade material at each bore hole, revealing subgrade CBR's of 3%-8%. The existing pavement structure was also revealed to consist of 150mm of bitumen and base course gravel. An extract of the geotechnical investigation can be found in the appendix.

5.2.1 Pavement Design

In 2009 FCRC commissioned a design to reconstruct Main St Hervey Bay, using the geotechnical investigation undertaken 9 years' prior as the basis for design. The following assumptions were made:

- 7% heavy vehicles
- 4.5% traffic growth
- 25 year design period

Using traffic count data, a DESA of 8.36×10^6 ESA's and the design subgrade CBR of 3% was used, as per the geotechnical investigation. Two pavement designs were produced, one for the intersection with Urraween Road and one for the traffic lanes, as shown below.

Intersection		Traffic Lane	
• Surfacing	50mm DG14 10mm C170 seal	• Surfacing	50mm DG14 10mm C170 seal
• Base course	150mm DG20	• Base course	200mm type 2.1 (Min CBR 85%)
• Base course	200mm type 2.1 (Min CBR 80%)	• Subbase course	300mm selected fill (Min CBR 10%)
• Subbase course	100mm type 2.3 (Min CBR 45%)		

As can be seen, the minimum pavement depth is 550mm, with a non-structural layer of 50mm DG14 asphalt. The intersection design allows for a structural layer of 150mm DG20 asphalt. The selected fill was nominated as minimum CBR 10 material.

To improve drainage conditions along Main St, kerb and channel and road side drainage structures were included in the design to allow for Q100 immunity, as per the Queensland Urban Drainage Manual (QUDM). Due to the moisture character of the clay subgrade found in the geotechnical investigation, subsoil drains were allowed for underneath the kerb invert.

5.2.2 Construction

In November 2009, construction commenced on the reconstruction of Main St Hervey Bay, for the tendered amount of $5,586,192.76 with an expected project duration of 37 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Trench and place subsoil drains
- Reconstruct subbase course
- Construct kerb and channel
- Reconstruct base course
- Asphalt surfacing

Figure 5.2: Main Street Hervey Bay – Construction

The as constructed price of the project totalled $5,713,757.86, with variation works being undertaken primarily for extra drainage works. Due to inclement weather and extensions of time for works associated with variations, the total project duration exceeded the expected program by 18 weeks, totalling 55 weeks.

5.2.3 Investigation

A site investigation of Main St Hervey Bay revealed that there are extensive pavement failures present and by visual inspection, the road is unlikely to reach its expected service life. Figure 5.3 is indicative of the failures present. The site visit record can be found in the appendix.

Figure 5.3: Main Street Hervey Bay – Pavement Condition

As can be seen, there is extensive crocodile cracking in the wheel path, combined with some rutting. This is consistent for approximately half of the length of the project and indicates a failure in the pavement or subgrade. The open cracks will allow moisture ingress, further degrading the pavement material, however this failure typically requires more rigorous treatment than resurfacing. There was also evidence of minor patching, flushing and at the time of inspection the kerb and channel and drainage structures were in good condition with no evidence of silt which indicates good drainage conditions.

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.4 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

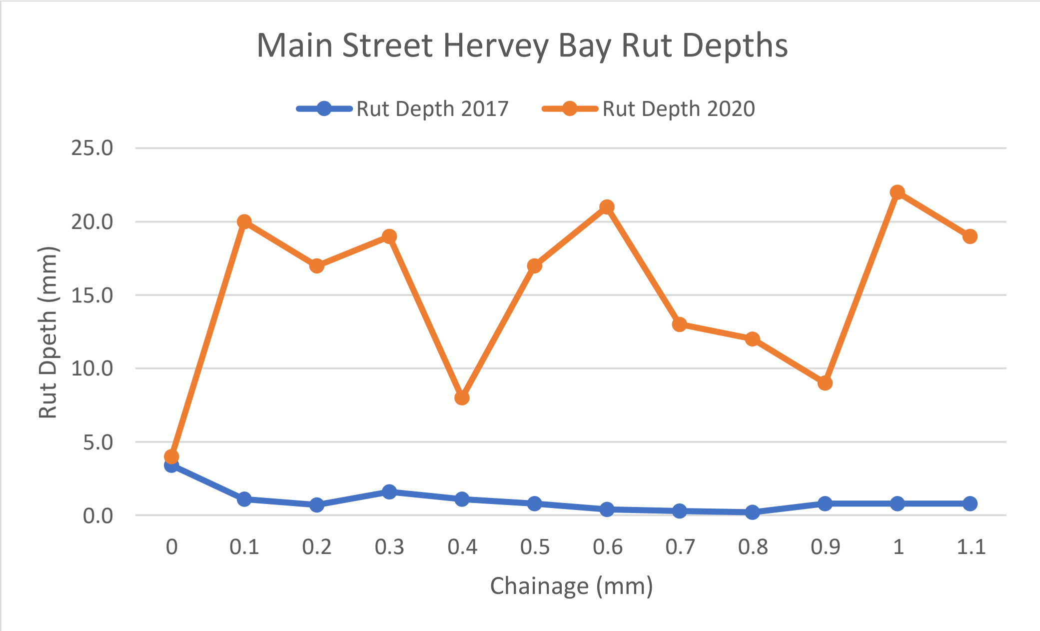

Figure 5.4: Main St Hervey Bay - Rut Depth

It can be seen from the above figure that the maximum rut depth identified at Main St in 2017 was 3mm. This does not correlate with the site inspection conducted which noted greater rut depths, indicating a greatly depreciated surface within the 3 year time frame. The locations of the 2017 rut depths were mapped and then manually measured with a straight edge and a tape measure for comparison. While some of these figures are large, there were other locations within the project extents which had exhibited more significant rutting and deflection.

At the time of the 2017 AARB survey, the road formation was 7 years old and had exhibited minimal rutting but significant pavement failures for its age with the maximum rut depth occurring at Chainage 0. Main St Hervey Bay [2017] displayed rutting severity ranges of 0-5mm for 100% of the project. Meanwhile, the severity range of rutting measured in 2020 shown in table 5.1 indicate the condition of the pavement has significantly worsened in the last 3 years.

Table 5.1: Severity of rut depth at Main St Hervey Bay

Rut Severity Range (mm)	Extent of Project (%)
0-5	8.33%
5-10	16.67%
10-15	16.67%
15-20	41.67%
20-25	16.67%

As can be seen, at the maximum Main St is rutting at a rate of 11mm/year which far exceeds the allowable 1mm/year, as defined by AAPA.

Geotechnical information obtained from FCRC, contained in table 5.1 demonstrates the compaction achieved by the contractor on each of the pavement layers in a section which has demonstrated heavy failure. FCRC specification requires that 100% standard compaction be achieved which is confirmed by the geotechnical report.

Table 5.1: Main St Hervey Bay Pavement Density (FCRC, 2010)

Pavement Layer	Density Ratio (%)
Base	102.6
Subbase	100.2
Lower Subbase	101.4

Discussions with FCRC staff revealed that Main St Hervey Bay first exhibited signs of crocodile cracking within 2 years of construction, indicating a potential construction issue with the pavement. It is evident that the extent of deformations identified in the site investigation suggest that much of the pavement is beyond repair with resurfacing treatment and will require reconstruction at a stage 15 years prior to the end of design life.

5.2.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.10 and the given DESA value. A second design check was then conducted using the most recent available traffic data.

The road pavement was designed based on an AADT of 8400 in 2009 with an anticipated 4.5% growth factor, meaning that AADT in 2020 should be 13,631. Investigation of FCRC’s latest available traffic count data (2019) indicates an AATD of 13,241 which is below the anticipated traffic volume and equated to a 4.22% growth rate.

The design check, using Figure 3.10 indicated a minimum pavement thickness of 500mm. As such, the constructed profile was adequate for the assumed AADT and traffic assumptions with an extra 50mm of depth. The revised design check was done after calculating the DESA as 6.35×10^{6} using an AADT of 13,241 and a growth rate of 4.22%. The chart indicated a minimum pavement thickness of 480mm. This revealed that the original pavement design was sufficient for the actual traffic data and growth as indicated by FCRC's most recent traffic counts. This supports the hypothesis that the overall cause of pavement failure has not been the structural design but is more likely caused by a construction issue or contaminated pavement materials. In fact, even the possibility of subsoil drains not being correctly placed and connected could be responsible for saturation of the subgrade and granular pavement material.

5.3 Chapel Road Hervey Bay

Chapel Road Hervey Bay was identified for reconstruction in the 15/16 financial year due to the range of extensive pavement failures and poor shape of the existing road, as indicated in figure 5.6. Chapel Road is a collector road which connects the main road between Maryborough and Hervey Bay with many connection roads.

Figure 5.6: Chapel Road Hervey Bay - Existing Formation

The existing road structure consisted of a 7.0m wide formation with table drains either side and no sealed shoulders. In 2014, FCRC commissioned a geotechnical investigation to determine the underlying geological conditions of the road as well as to analyse the existing pavement structure. A total of 5 bore holes were drilled with soaked CBR tests undertaken on subgrade material and DCP's taken in each hole. The investigation revealed a moderately plastic subgrade with some evidence of rock and granular material.

5.3.1 Pavement Design

In 2015, FCRC commission a design to reconstruct 1150m of Chapel Road Hervey Bay, using the geotechnical investigation and traffic count data as the basis for the design. The following assumptions were made:

- 13% heavy vehicles
- 3% traffic growth
- 40 year design period

Using traffic count data, a DESA of 4.48×10^6 ESA's and the design subgrade CBR of 4% was used, as per the geotechnical investigation. The following pavement design was selected:

• Primerseal	1.2 L/m^2 C170 AMC4
	10mm Aggregate $1m^2/120m^2$
• First Seal	1.8 L/m^2 S35E 3% cutter
	16mm Aggregate $1m^2/110m^2$
• Second Seal	1.0 L/m^2 S35E 3% cutter
	7mm Aggregate $1m^2/250m^2$
• Base course	165mm type 2.1 CTB 3%
• Subbase course	135mm type 2.1 CTB 3%

As can be seen, there is a total pavement depth of 300mm with a PMB double/double seal for surfacing. To improve the drainage conditions of the road, the design calls for table drain reformation, construction of drainage structures and installation of RCP's. The design also allows for sealed shoulders, adding 3.0m to the total width of the formation.

5.3.2 Construction

In October 2015, construction commenced on the reconstruction of Chapel Road Hervey Bay for the tendered amount of $1,236,678.25 with a duration of 12 weeks. The contractor pursued the following programme of works:

- Excavate for RCP’s and box culvert
- Install drainage structures
- Box out for new pavement
- Reconstruct subbase course
- Reconstruct base course
- Bitumen seal

Figure 5.7: Chapel Road Hervey Bay – Construction

The as constructed price of the project totalled $1,280,615.67, with some minimal variation work being undertaken to remove and replace unsuitable subgrade material.

5.3.3 Investigation

A site investigation of Chapel Road Hervey Bay revealed that the reconstructed road pavement has exhibited little evidence of deformation and has retained its shape fairly well. However, there is evidence of extensive flushing in the wheel paths over the entire length of the project, as shown in figure 5.8. The site visit record and pavement defect mapping sheet may be found in the appendix.

Figure 5.8: Chapel Road Hervey Bay – Pavement Condition

The extent of the flushing and the age of the road indicate that the spray rate for the bitumen seal was either too heavy or the traffic count data was not correct. If a traffic count is under-estimated, then the spray rate will be too high for the road, causing wheel loads to embed the aggregate into the binder to such an extent that it becomes submerged.

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.9 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

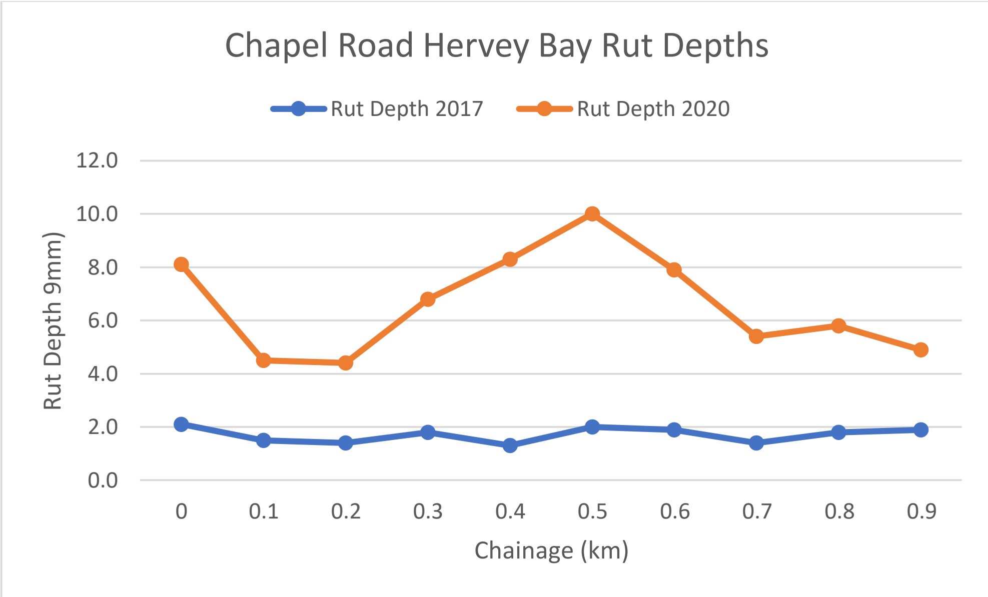

Figure 5.9: Chapel Road Hervey Bay - Rut Depths

It can be seen that in 2017, the maximum rut depth was just over 2.0mm at chainage 700 and the minimum rut depth was 1.9mm at chainage 400. According to APPA, the anticipated rate of rutting in flexible pavements is 1mm/year. In 2017, Chapel Road exhibited rut depths with a severity range of 0-5mm for 100% of the project. While Austroads does not consider this to be significant, the road was 2 years old and as such should not have exhibited any rut depths of greater than 2mm. This demonstrates a maximum rate of rutting of 2.67mm/year By contrast, the manually measured rut depths indicate severity ranges of 0-5mm and 5-10mm of 44% and 66% respectively.

5.3.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.10 and the given DESA value. A second design check was then conducted using the most recent available traffic data.

The most recent traffic count data for Chapel Road from FCRC's records is from 2017 and indicates an AADT of 2025 with 17.4% heavy vehicles. The design allowed for an AADT of 1075 and 13% heavy vehicles based on a traffic count from 2012. Evidently, the estimated traffic used in the design was grossly underestimated. In fact, the 2017 data suggests a growth rate of 13.5% pa, if the 2012 data can be considered accurate. This failure to correctly estimate the traffic growth can be seen as the cause of the extensive flushing in the wheel paths.

The design check, undertaken using Figure 3.10, indicated a minimum pavement thickness of 400mm, which is more than the allowed 300mm. However, since the pavement materials are cement treated, a second check was done using CIRCLY. As per DTMR recommendation, the check was undertaken using a material modulus of 3500MPa for the 3% cemented type 2.1 material used to construct Chapel Road (DTMR, 2020). This was modelled as one single layer on CIRCLY with an Ndt of 4.48×10^6 as per the design. This revealed that the constructed profile was slightly inadequate for the assumed AADT and traffic assumptions, demonstrating early failure in the CTB. The revised design was done after calculating the Ndt as 1.66×10^8 road using an AADT of 2025 and a growth rate of 13.5%. This revealed that the total pavement depth should have been increased by 105mm to satisfy the 40 year design period.

It is recognised that the growth rate of 13.5% is unusually high and is more likely the result of an incorrect AADT value being used in the original design, rather than a large increase in traffic volumes over recent years. However, in the absence of a new traffic analysis, the rate of 13.5% was used for the purposes of this analysis.

5.4 South Doolong Road Hervey Bay

South Doolong Road Hervey Bay was identified as in need of reconstruction as part of Council’s 2014/2015 capital works program. The road had seen significant growth in traffic due to new residential developments being constructed and as such the existing formation was not considered adequate and was exhibiting extensive deformation and patching, as shown in Figure 5.10. South Doolong Road is a collector road, connecting new residential developments and an established school with other suburbs in Hervey Bay.

Figure 5.10: South Doolong Road Hervey Bay - Existing Formation

The existing road structure consisted of a 9.0m wide road including shoulders with table drains either side, no kerb and channel or drainage structures. In 2014, FCRC commissioned a geotechnical investigation to determine the underlying geological conditions of the road as well as to analyse the existing pavement structure. A total of 6 bore holes were drilled with soaked CBR tests undertaken on subgrade material and DCP's taken in each hole. The investigation revealed a sandy clay subgrade of medium plasticity.

5.4.1 Pavement Design

In 2015, FCRC commission a design to reconstruct 800m of South Doolong Road Hervey Bay, using the geotechnical investigation and traffic count data as the basis for the design. The following assumptions were made:

- 2.6% heavy vehicles
- 3% traffic growth
- 30 year design period

Using traffic count data, a DESA of 9.60×10^5 ESA's and the design subgrade CBR of 4% was used, as per the geotechnical investigation. The following pavement design was used:

- First Seal — $1.4\ L/m^2$ C170 3% cutter
  14mm Aggregate $1m^2/110m^2$
- Second Seal — $0.7L/m^2$ C170 3% cutter
  7mm Aggregate $1m^2/250m^2$
- Base course — 125mm type 2.1
  (Min CBR 80%)
- Subbase course — 125mm type 2.3
  (Min CBR 45%)
- Select Fill — 200mm type 2.5
  (Min CBR 15%)

As can be seen, there is a total pavement depth of 450mm, including select fill, with a C170 double/double seal for surfacing. To improve the drainage conditions of the road, the design calls for table drain reformation, construction of some kerb and channel and installation of drainage culverts. The design also widened the formation by 1.0m.

5.4.2 Construction

In October 2015, construction commenced on the reconstruction of South Doolong Road for the tendered amount of $763,168 with a duration of 16 weeks. The contractor pursued the following programme of works:

- Excavate for RCP's and box culvert
- Install drainage structures
- Box out for new pavement
- Reconstruct subbase course
- Reconstruct base course
- Bitumen seal

The as constructed price of the project totalled $1,247,569.67, with extensive variation work being undertaken to remove and replace unsuitable subgrade material. The records indicate that $1368m^3$ of subgrade was removed and replaced, which at a depth of 200mm means that 85.5% of the subgrade was replaced.

5.4.3 Investigation

A site investigation of South Doolong Road Hervey Bay revealed that the reconstructed road pavement has exhibited little evidence of deformation and has generally retained its shape. However, there is evidence of some flushing in the wheel paths, ravelling and minor rutting, as shown in Figure 5.11. The site visit record and pavement defect mapping sheet may be found in the appendix.

Figure 5.11: South Doolong Road Hervey Bay – Pavement Condition

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.12 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

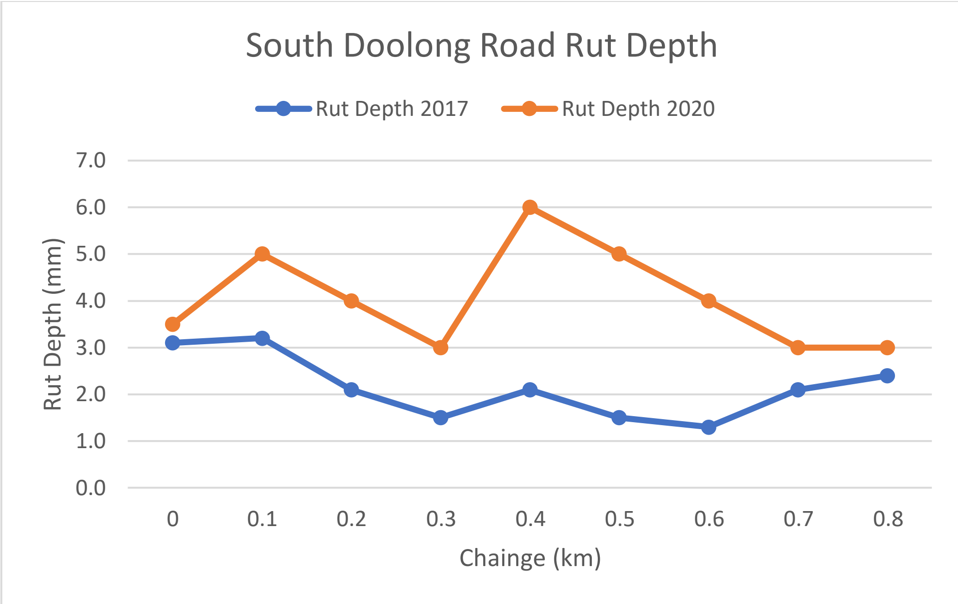

Figure: 5.12 South Doolong Road Hervey Bay - Rut Depth

As can be seen from the above figure, there has been an increase in rut depth since 2017, however it has been minimal. The maximum rut depth occurs at chainage 400m where a rut depth of 6mm was noted, suggesting a rutting rate of 1.2mm/year, slightly exceeding the acceptable 1mm/year benchmark. In 2017, South Doolong road had a rutting severity range of 0-5mm over 100% of the project. While in 2020, severity ranges of 0-5mm and 5-10mm were 89% and 11% respectively. Since Austroads does not consider rut depths less than 10mm to be significant, it can be seen the pavement is performing well for its age.

The investigation into South Doolong road revealed that the constructed pavement is generally performing as expected with little evidence of deformation. The surface flushing and ravelling suggests either an issue with the placement of the double/double seal or an inaccurate traffic count used to design the seal as there is excess binder in some locations and not enough in others. This issue can be easily remedied with a reseal, paying special attention to the flushed and ravelling areas, ultimately extending the roads serviceable life. From the investigation it is apparent that in general South Doolong Road should reach its design life with adequate maintenance and some minimal pavement repairs later in its life.

5.4.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.10 and the given DESA value. A second design check was then conducted using the most recent available traffic data.

The most recent traffic count data for South Doolong Road available in FCRC's records is from 2019 which indicates an AADT of 4018 while the design AADT was 1223 based on 2012 traffic data. This indicates a growth rate of 18.38%. In the 7 years from 2012 to 2019, the area has seen several housing development constructed which is the likely cause of the large change in traffic growth.

The design check, undertaken using Figure 3.10, indicated a minimum pavement depth of 325mm, which is less than the allowed 450mm when including select fill. As such, the original design more than adequate for the input parameters. The second design check, using the most recent traffic data and a DESA of 4.12×10^7, indicated a minimum pavement depth of 500mm, meaning that the pavement depth would have to be increased by 50mm. This could be achieved with a 50mm asphalt overlay.

It is recognised that the growth rate of 18.38% is unusually high and is more likely the result of an incorrect AADT value being used in the original design, rather than a large increase in traffic volumes over recent years. However, in the absence of a new traffic analysis, the rate of 18.38% was used for the purposes of this analysis.

Since the extent of the defects at South Doolong Road is limited to the surface, it can be deduced that the C170 seal has been insufficient for the much higher than expected traffic volumes. If a PMB binder were used in lieu of the C170 and the seal designed for the correct amount of traffic, then the surface would have greater resistance the high stresses which it is subject to.

5.5 Oleander Avenue Hervey Bay

Oleander Avenue Hervey Bay was identified for reconstruction as part of FCRC's 2015/2016 financial year capital program. The existing road formation had demonstrated extensive failures, crocodile cracking and patching as shown in Figure 5.13. Oleander Avenue is a controlled distributor road in the network's hierarchy and is a significant piece of infrastructure which allows transport from the suburb of Urangan to Pialba.

Figure 5.13: Oleander Avenue Hervey Bay - Existing Formation

The existing road was a 12.0m formation with two 3.5m wide traffic lanes and two 2.5m wide shoulders to allow for vehicle parking. Oleander Avenue also had kerb and channel on both sides which was in poor condition, much of which required replacing.

In 2015, FCRC commissioned a geotechnical investigation to determine the underlying geological conditions of the road as well as to analyse the existing pavement structure. A total of 8 bore holes were drilled with soaked CBR tests undertaken on subgrade material and DCP's taken in each hole. The investigation revealed a sandy clay subgrade of high plasticity with a minimum CBR value of 2%.

5.5.1 Pavement Design

In 2015, FCRC commission a design to reconstruct 1500m of Oleander Avenue Road Hervey Bay, using the geotechnical investigation and traffic count data as the basis for the design. The following assumptions were made:

- 1.6% heavy vehicles
- 4% traffic growth
- 40 year design period

Using traffic count data, a DESA of 5.60×10^5 ESA's and the design subgrade CBR of 2% was used, as per the geotechnical investigation. The project was designed in 3 sections, each with varying pavement profiles due to subgrade conditions. The purposes of this investigation will focus on the 425m section with the following pavement design:

- Surfacing — 30mm DG10 AB5
- Primer Seal — $1.2L/m^2$ C170
10mm Aggregate $1m^2/135m^2$
- Base course — 125mm type 2.1
(Min CBR 80%)
- Subbase course — 125mm type 2.3
(Min CBR 45%)
- Subbase course — 200mm type 2.5
(Min CBR 15%)
- Lower subbase course — 300mm rock blanket

As can be seen, there is a total pavement depth of 750mm including a 30mm asphalt wearing course. This is considered to be a very deep pavement and was considered necessary to reach the 40 year design life and bridge the CBR 2% subgrade. FCRC records indicate that type 2.1 gravel used in lieu of type 2.3 for the subbase as a variation for the convenience of the contractor.

5.5.2 Construction

In May 2016, construction commenced on the reconstruction of Oleander Avenue Hervey Bay for the tendered amount of $1,290,920.97 with a duration of 12 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Trench and place subsoil drains
- Reconstruct subbase course

- Construct kerb and channel
- Reconstruct base course
- Asphalt surfacing

Figure 5.14: Oleander Avenue Hervey Bay – Construction

The as constructed price of the project totalled $1,470,738.99, with variation works being undertaken primarily to place and compact additional road base material and surfacing for extended extents of the project. Due to inclement weather and extensions of time for works associated with variations, the total project duration exceeded the expected program by 13 weeks, totalling 25 weeks.

5.5.3 Investigation

A site investigation of Oleander Avenue Hervey Bay revealed that the reconstructed road pavement has exhibited little evidence of deformation and is in good condition. There was no evidence of surface or pavement failures, as indicated in Figure 5.15. The site visit record and pavement defect mapping sheet may be found in the appendix.

Figure 5.15: Oleander Avenue Hervey Bay – Pavement Condition

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.16 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

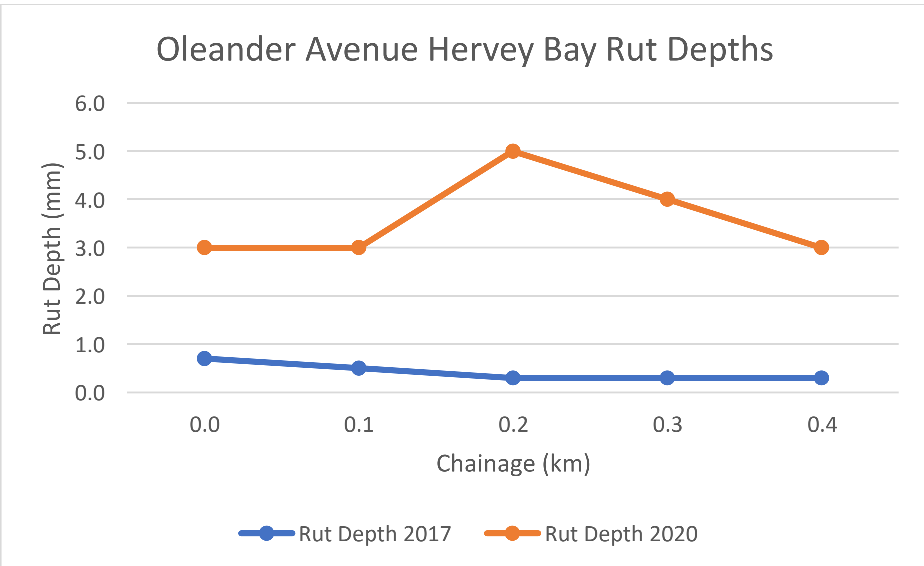

Figure 5.16: Oleander Avenue Hervey Bay - Rut Depths

It can be seen in Figure 5.16 that the rut depths observed at Oleander Avenue, in both 2017 and 2020, exhibited a severity range of 0-5mm for 100% of the project, indicating a well performing pavement. In fact, the average rate of rutting is less than the acceptable 1mm/year as suggested by AAPA while Oleander Avenue is demonstrating a maximum rate of rutting of 1.5m/year.

5.5.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.11 and the given DESA value. A second design check was then conducted using the most recent available traffic data.

The design for Oleander Avenue was based on an AADT of 4016 from 2010 traffic count data. The most recent available data from FCRC's records for Oleander Avenue is from 2018 which specifies an AADT of 4554, indicating a growth rate of 1.59%, far less than the assumed 4% growth factor.

The design check, undertaken using Figure 3.10, indicated a minimum pavement depth of 450mm, far less than the allowed 750mm. As such, the original pavement design is more than adequate for the input parameters. The alternative design was undertaken using the most recent traffic data available from FCRC which produced a DESA of 1.91×10^{6} due to an increase in heavy vehicles. This produced a minimum pavement thickness of 520mm, revealing that the original pavement design was sufficient. The overall pavement thickness could have been reduced by 230mm, resulting in a significant cost saving for rate payers.

5.6 Amity Street Maryborough

Amity Street Maryborough was identified as being in need of reconstruction as part of Council's 2014/2015 capital works program. The existing road had demonstrated severe failures and was at the end of its serviceable life, as indicated in figure 5.15. FCRC records do not contain photos of Amity St prior to reconstruction, however Google Street View was used to provide a look at the condition of the pavement. Amity St is a residential street located in suburban Maryborough which sees high levels of passenger cars due to its close locality to a school.

Figure 5.15: Amity St Maryborough - Existing Formation (Google, 2020)

The existing formation of 12m at Amity St was reinstated with the existing kerb and channel remaining due to its good condition. Only minor kerb and channel repairs were made including new road gully units. FCRC commissioned a geotechnical investigation to identify the underlying ground conditions with 4 bore holes being drilled and soaked CBR’s being taken at subgrade level of each of those holes. The investigation revealed silty clay material with high plasticity and a subgrade CBR of 4% which was used as the basis of the pavement design.

5.6.1 Pavement Design

In 2014, FCRC undertook an internal design of the Amity St reconstruction project using the available geotechnical and traffic count data. The following assumptions were made:

- 20 year design period

The design subgrade CBR of 4% was used, as per the geotechnical investigation. The following pavement design was selected:

- First Seal — 1.4 L/m^2 C170
  14mm Aggregate $1m^2/95m^2$
- Second Seal — $0.7L/m^2$ C170
  7mm Aggregate $1m^2/180m^2$
- Base course — 200mm type 2.1
  (Min CBR 80%)
- Subbase course — 200mm type 2.3
  (Min CBR 45%)

As can be seen there is a total pavement depth of 400mm of granular material, topped with a double/double C170 seal, as it standard for residential streets in Maryborough. This is considered to be a simple pavement design, using DTMR standard and readily available materials.

5.6.2 Construction

In February 2015, construction commenced on the reconstruction of Amity Street Maryborough for the quoted amount of $215,946.68 with a duration of 3 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Reconstruct subbase course
- Isolated kerb and channel repairs
- Install RGU’s
- Reconstruct base course
- Bitumen surfacing

Figure 5.16: Amity St Maryborough – Construction

The as constructed price of the project totalled $305,086.97, with variation works being undertaken primarily replace unsuitable subgrade material. Extensions of time were granted for variation work bringing the project to a total of 5 weeks.

5.6.3 Investigation

A site investigation to Amity St Maryborough revealed that the constructed pavement exhibited minimal deflection or failures and that the seal surface was generally in good condition, as indicated in Figure 5.17.

Figure 5.17: Amity Street Maryborough – Pavement Condition

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.4 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

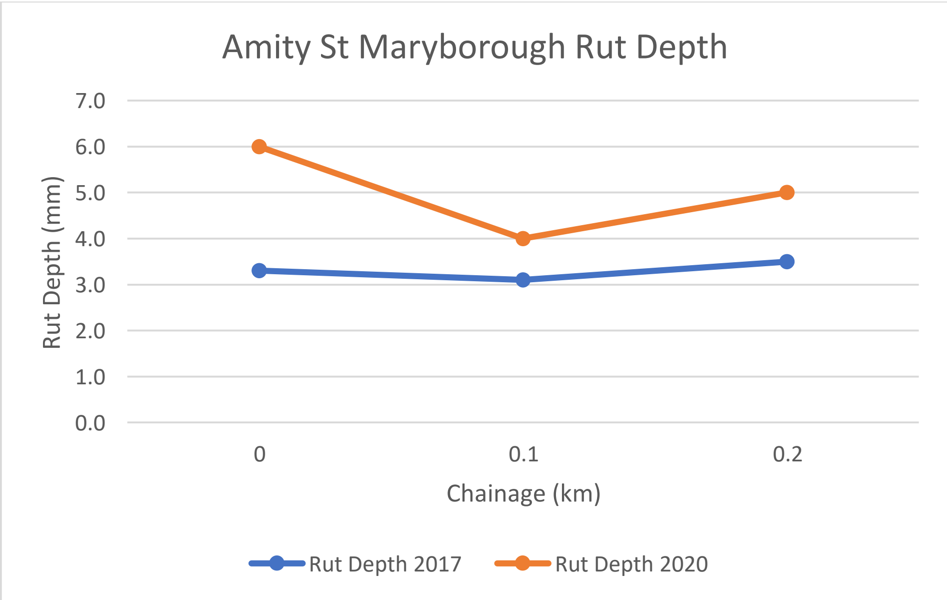

Figure 5.18: Amity Street Maryborough – Rut Depths

At the time of the 2017 AARB survey, Amity St Maryborough was 3 years old and had exhibited minimal signs of rutting or deformation. The condition data suggests that the maximum rut depth in 2017 was 3.5mm, indicating a well performing pavement. In fact, 100% of the roads measured rut depths had a severity of 0-5mm, which is regarding as largely insignificant. The 2020 investigation revealed that the rut depths had increased and the severity ranges include 0-5mm and 5-10mm over 66% and 33% respectively. Amity St has demonstrated a maximum rate of rutting of only 0.9mm/year. Overall, the pavement at Amity St appears to be performing well for its age and with scheduled maintenance should easily reach its service life. Accurate traffic count data is not available for Amity St Maryborough.

5.6.4 Design Check

Limited design and traffic data was available for Amity St so it was difficult to conduct an accurate design check. In fact, with no DESA value, Figure 3.10 could not be used. However, by comparison with other investigated roads and the assumed low traffic volumes, it is reasonable to assume that the 400mm of pavement provided at Amity St is sufficient.

5.7 Yerra Road Maryborough

Yerra Road Maryborough was identified as in need of reconstruction as part of Council's 2015/2016 financial year capital program. Yerra Road is a Rural Arterial road in the network hierarchy and is an important piece of infrastructure as it connects the rural community with Mungar and Maryborough. Yerra Road has a high volume of heavy vehicles due to the cane farms in the area as well as a local quarry being located on the road. The existing road formation, shown in Figure 5.18 was a 6.0m formation with unsealed shoulders and an undulating surface.

Figure 5.18: Yerra Road Maryborough - Existing Formation

In 2013 FCRC commissioned a geotechnical investigation into the underlying subgrade material at Yerra Road. A total of 12 bore holes were drilled, revealing a medium plasticity silty clay subgrade with some evidence of fractured rock. Soaked CBR tests were undertaken on subgrade material and DCP's taken in each hole. The investigation revealed a sandy clay subgrade of high plasticity with a minimum CBR value of 5%.

5.7.1 Pavement Design

In 2015, FCRC commission a design to reconstruct 660m of Yerra Road Maryborough, using the geotechnical investigation and traffic count data as the basis for the design. The following assumptions were made:

- 39% heavy vehicles
- 1% traffic growth
- 40 year design period

Using traffic count data, a DESA of 1.7×10^6 ESA's and the design subgrade CBR of 5% was used, as per the geotechnical investigation. The following pavement design was used:

- First Seal — 1.6 L/m^2 C170
16mm Aggregate $1m^2/80m^2$
- Second Seal — $1.0L/m^2$ C170
10mm Aggregate $1m^2/135m^2$
- Base course — 135mm type 2.1
(Min CBR 80%)
- Subbase course — 145mm type 2.3
(Min CBR 45%)
- Lower Subbase course — 130mm select fill
(Min CBR 9%)

As can be seen, there is a total pavement depth of 410mm surfaced with a double/double C170 seal, as is standard for use on rural arterial roads. It was expected that this pavement design would be sufficient to service the high volume of heavy vehicles on Yerra Road.

5.7.2 Construction

In September 2015, construction commenced on the reconstruction of Yerra Road Maryborough for the tendered amount of $331,993.10 with a duration of 6 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Place and compact selected fill
- Reconstruct subbase course
- Reconstruct base course
- Bitumen surfacing

Figure 5.19: Yerra Road Maryborough – Construction

The as constructed price of the project totalled $379,275.08, with variation works being undertaken primarily to remove unsuitable subgrade material and replace with rock mattress. Due to inclement weather and extensions of time for works associated with variations, the total project duration exceeded the expected program by 12 weeks, totalling 18 weeks

5.7.3 Investigation

A site investigation to Yerra Road Maryborough revealed that the constructed pavement exhibited signs of pavement failure and surface distress, as shown in Figure 5.20.

Figure 5.20: Yerra Road Maryborough – Pavement Condition

While there is minimal cracking, it can be seen there is evidence of flushing and some deformation and rutting, indicating a possible subgrade failure. Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.21 is a plot of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

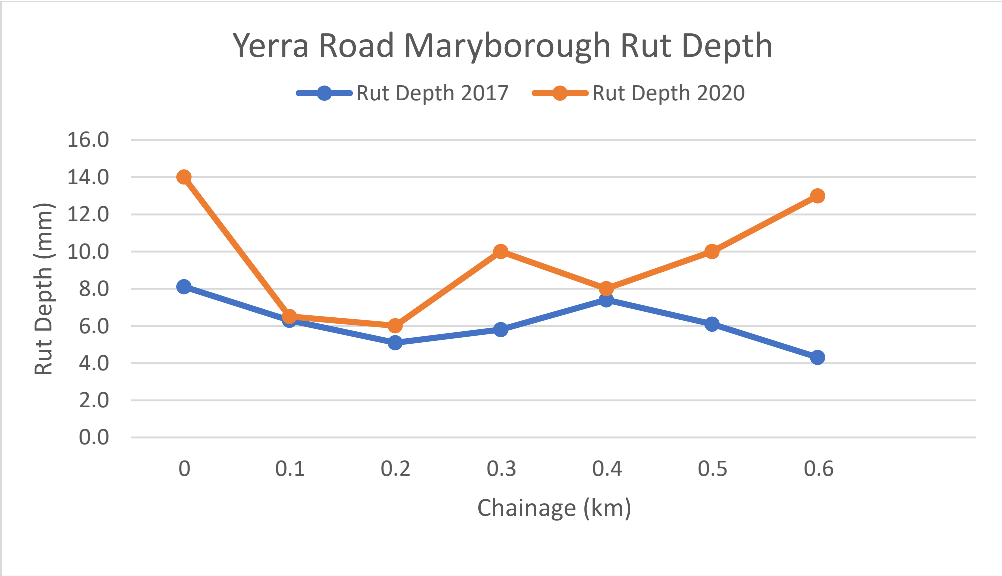

Figure 5.21: Yerra Road Maryborough – Rut Depths

At the time of the 2017 AARB survey, the road formation was 2 years old and had exhibited significant rutting for its age. This suggests serious subgrade failures and indicates an inadequate pavement profile. Yerra road [2017] displayed rutting severity ranges of 0-5mm and 5-10mm for 25% and 72% respectively. While Austroad's does not consider rutting of less than 10mm to be significant, this extent of rutting is not to be expected on a 2 year old pavement. The extent of rutting in 2020 can be seen to have worsened and has severity ranges of 5-10mm and 10-15mm of 43% and 57% respectively. Yerra Road has demonstrated a maximum rate of rutting of 3mm/ year.

5.6.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.11 and the given DESA value. A second design check was then conducted using he most recent available traffic data.

The latest traffic count data available in FCRC's records is from 2020 and indicates an AADT of 129, with a commercial vehicle content of 26%. Compared with the design AADT of 150, this accounts to a growth rate of approximately -2%, less than the assumed 1%. It is important to consider that Yerra Road is heavily trafficked by cane trucks during cane harvesting season only, and as such the time of year in which the traffic count is undertaken is of paramount importance. The 2020 count ended in July 2020 which is during cane season so this count would be inflated.

The design check, undertaken using Figure 3.11, indicated a minimum pavement depth of 320mm, less than the allowed 410mm. Indeed, the pavement design was more than sufficient for the input parameters. The second design check, using the most recent traffic data and a DESA of 9.28×10^5 revealed a minimum pavement depth of 300mm, meaning that the pavement could have been reduced by 110mm. However, this is in contrast to the performance of the pavement which indicates an underlying issue. The extent of the deformation and distress suggests that there are extraneous factors influencing the pavement performance. On review of the geotechnical report it is evident that there is evidence of medium plasticity soil, indicating expansive potential. Therefore, it is expected that the presence of expansive soil has impacted the performance of the pavement.

5.8 Beaver Rock Road Maryborough

Beaver Rock Road Maryborough was identified for reconstruction in the 15/16 financial year due to the range of extensive pavement failures and poor shape of the existing road, as indicated in figure 5.22. Beaver Rock Road is a rural arterial road which provides access to rural properties and the lower Mary River. The existing road formation was a 6.5m, low lying road with minimal drainage causing extensive failures.

Figure 5.22: Beaver Rock Road Maryborough - Existing Formation

In 2014 FCRC commissioned a geotechnical investigation to determine the underlying subgrade conditions and test the existing pavement material at Beaver Rock Road Maryborough. A total of 13 boreholes were drilled, revealing a moderate to high plasticity, silty clay subgrade. Soaked CBR tests were undertaken on subgrade material and DCP's taken in each hole. The investigation revealed subgrade soaked CBR values of 3.1% to 15%.

5.8.1 Pavement Design

In 2015, FCRC commissioned a design to reconstruct approximately 3.2km of Beaver Rock Road over various financial years. This investigation will focus on the 1000m section which was reconstructed in 2016. The following assumptions were made:

- 12.15% heavy vehicles
- 3% traffic growth
- 40 year design period

Using traffic count data, a DESA of 5.65×10^5 ESA's and the design subgrade CBR of 3% was used, as per the geotechnical investigation. The following pavement design was used:

• First Seal	1.8 L/m^2 C170 16mm Aggregate $1m^2/90m^2$
• Second Seal	$0.9L/m^2$ C170 7mm Aggregate $1m^2/250m^2$
• Base course	100mm type 2.1 (Min CBR 80%)
• Subbase course	100mm type 2.3 (Min CBR 45%)
• Lower Subbase course	200mm select fill (Min CBR 9%)

As can be seen, there is a total pavement depth of 400mm surfaced with a double/double C170 seal, as is standard for use on rural arterial roads. Extensive testing was undertaken on the existing pavement material to determine if it could be re-used or could be a potential candidate for in-situ stabilisation. Due to the poor quality of the material it was determine unsuitable but was appropriate to be incorporated in the new road embankment and subgrade. The design also called for raising the existing formation by 0.5m and widening it to a full 8.5m two lane road with sealed shoulders.

5.8.2 Construction

In September 2015, construction commenced on the reconstruction of Beaver Rock Road Maryborough for the tendered amount of $589,574.55 with a duration of 14 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Place and compact selected fill
- Reconstruct subbase course
- Reconstruct base course
- Bitumen surfacing

Figure 5.23: Beaver Rock Road Maryborough Construction

The as constructed price of the project totalled $843,022.94 with variation works being undertaken primarily to remove unsuitable subgrade material and replace with rock mattress and CBR 10 material.

5.8.3 Investigation

A site visit to Beaver Rock Road Maryborough revealed that the constructed pavement appeared to be in fair condition with some minor flushing and rutting evident as shown in Figure 5.24.

Figure 5.24: Beaver Rock Road Maryborough – Pavement Condition

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.25 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

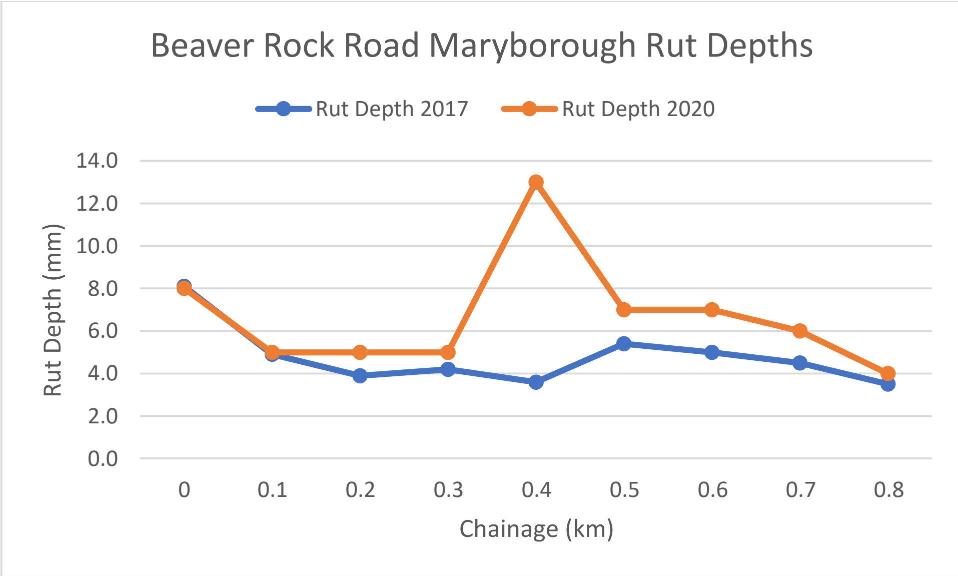

Figure 5.25: Beaver Rock Road Maryborough – Rut Depths

At the time of the 2017 AARB survey, the road formation was 1 year old and had exhibited significant rutting for its age with the maximum rut depth occurring at Chainage 0. This suggests subgrade or pavement failures. Beaver Rock road [2017] displayed rutting severity ranges of 0-5mm, 5-10mm and 10-15mm for 60%, 30% and 10% respectively. The extent of rutting in 2020 can be seen to have worsened, exhibiting severity ranges of 0-5mm, 5-10mm and 10-15mm for 44.5%, 44.5% and 11% respectively. Beaver Rock Road has demonstrated a rate of rutting of 3mm/year.

5.6.4 Design Check

In order to determine the effectiveness of the pavement design, a check was undertaken with the Austroads chart in Figure 3.11 and the given DESA value. A second design check was then conducted using he most recent available traffic data.

The most recent traffic count data available for Beaver Rock Road is from 2020 and indicates an AADT for 204, while the design indicates an AADT of 221 in 2012. This suggests that the road has seen a negative growth rate. However, it is important to consider that Beaver Rock Road is heavily trafficked by cane trucks during cane harvesting season only, and as such the time of year in which the traffic count is undertaken is of paramount importance. The 2020 count ended in April 2020 which is considered to be the start of cane season in the Fraser Coast. The timing of the traffic count diminishes the accuracy of the data and does not provide a good understanding of the current traffic conditions on Beaver Rock Road Maryborough.

The design check, undertaken using Figure 3.11, indicated a minimum pavement depth of 360mm, less than the allowed 400mm. Indeed, the original design was more than sufficient was the input parameters. The second design check was done using the calculated DESA of 5.35×10^5, indicated a minimum pavement depth of 355mm. As such, the constructed pavement should be sufficient for the traffic conditions. However, the geotechnical report revealed high plasticity soil, indicating a high expansive potential. Therefore, it is expected that expansive soil may have impacted the pavement causing the higher than expected rate of rutting.

5.9 Ward Street Maryborough

Ward Street Maryborough was identified for reconstruction as part of the FCRC's 2015/2016 financial year capital works programme. The existing road was 7m wide with unsealed shoulders and kerb and channel, as indicated in Figure 5.27. FCRC records do not contain photos of Ward St prior to reconstruction, however Google Street View was used to provide a look at the condition of the pavement. Ward Street is an access residential road in the road network hierarchy.

Figure 5.27: Ward Street Maryborough – Existing Formation (Google, 2020)

In 2015, FCRC commissioned a geotechnical investigation to determine the underlying subgrade conditions at Ward St Maryborough. A total of 5 bore holes were drilled which revealed a moderately plastic, silty clay material. Soaked CBR tests were undertaken on subgrade material and DCP's taken in each hole. The investigation revealed subgrade soaked CBR values of 2% to 8%.

5.9.1 Pavement Design

In 2014, FCRC undertook an internal design of the Amity St reconstruction project using the available geotechnical and traffic count data. The following assumptions were made:

- 20 year design period

The design subgrade CBR of 5% was used, as per the geotechnical investigation. The following pavement design was selected:

• First Seal	1.4 L/m^2 C170
	14mm Aggregate $1m^2/95m^2$
• Second Seal	$0.7L/m^2$ C170
	7mm Aggregate $1m^2/180m^2$
• Base course	190mm type 2.1
	(Min CBR 80%)
• Subbase course	150mm type 2.3
	(Min CBR 45%)

As can be seen there is a total pavement depth of 340mm of granular material, topped with a double/double C170 seal, as it standard for residential streets in Maryborough. The design called for new kerb and channel, drainage structures and widening of the existing formation to full 10.0m sealed width.

5.9.2 Construction

In July 2016, construction commenced on the reconstruction of Ward Street Maryborough for the quoted amount of $439,918.02 with a duration of 11 weeks. The contractor pursued the following programme of works:

- Remove existing road pavement and box out for new pavement
- Reconstruct subbase course
- Isolated kerb and channel repairs
- Install RGU's
- Reconstruct base course

- Bitumen surfacing

Figure 5.28: Ward Street Maryborough – Construction

The as constructed price of the project totalled $465,642.12, with variation works being undertaken primarily to place and compact additional road base material and surfacing for extended extents of the project. Extensions of time for works associated with variations, the total project duration exceeded the expected program by 3 weeks, totalling 15 weeks.

5.9.3 Investigation

A site investigation to Ward St Maryborough revealed that the pavement appeared to be in good condition, with no deformation or evidence of distress, as indicated in Figure 5.29. The seal was even found to be in good condition with minimal surface distress as displayed on most other pavements.

Figure 5.29: Ward Street Maryborough – Pavement Condition

Condition testing data was obtained from FCRC to compare with the physical site visit undertaken. Figure 5.30 is an illustration of rut depths measured in 2017 plotted against manually measured rut depths in 2020.

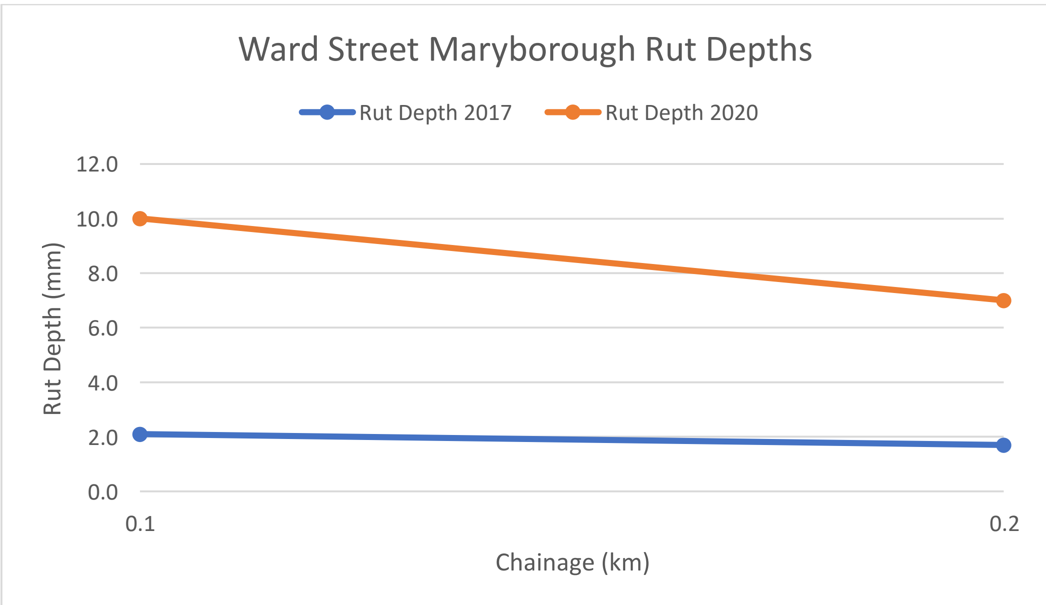

Figure 5.30: Ward Street Maryborough Rut Depths

At the time of the 2017 survey, Ward St was 12 months old and had demonstrated a maximum rut depth of 2.0 mm where 100% of measured depths were within the severity range of 0-5mm. Meanwhile, the 2020 the maximum rut depth has increased to 10mm where the severity ranges are 0-5mm and 5-10mm for 50% each. Ward St has demonstrated a maximum rate of rutting of 2.67mm/year. Overall, the pavement at Ward St appears to be performing well for its age and with scheduled maintenance should easily reach its service life. Accurate traffic count data is not available for Ward St Maryborough.

5.9.4 Design Check

Limited design and traffic data was available for Ward St so it was difficult to conduct an accurate design check. In fact, with no DESA value, Figure 3.10 could not be used. However, after comparison with other roads in this investigation and considering the assumed low traffic volume of Ward St, it can be reasonably assumed that the 340mm deep pavement is sufficient.

Chapter 6 - Comparison of Constructed Pavements

Costs for projects can vary greatly in the Fraser Coast depending on the volume of work available to the market, the scale of the project, the availability of skilled workers or resources and specialist project requirements.

This comparison considered the total overall costs of the projects to construct the pavement only as well as the time taken to construct each on a square meter basis. As revealed in Chapter 5, many of the projects required unsuitable subgrade to be removed, increasing the pavement thickness. This cost was also be included in the comparison to provide an encompassing evaluation of the effectiveness of the pavement design. To offer a fair comparison, the costs to construct kerb and channel, drainage structures and landscaping were removed from the project, as not all roads investigated had drainage works undertaken.

Table 6.1 ranks the constructed pavements based on the non-destructive evaluations undertaken during the site investigations from chapter 5.

Table 6.1: Rank of Constructed pavements

Rank	Location
1	South Doolong Road Hervey Bay
2	Amity Street Maryborough
3	Oleander Avenue Hervey Bay
4	Ward Street Maryborough
5	Beaver Rock Road Maryborough
6	Chapel Road Maryborough
7	Yerra Road Maryborough
8	Main Street Hervey Bay

Table 6.2 is a collation of the cost to construct only the pavements at each of the sites from Chapter 5 with a square meter cost comparison. It also converts the prices into 2019 values by using the inflation data from the Reserve Bank of Australia (RBA). Furthermore, it identifies the percentage of the project value (pavement construction cost only) which is attributed to subgrade replacement treatment. This is a useful tool when comparing the effectiveness of the

varying pavement profiles to bridge the subgrade material found in the Fraser Coast. This subgrade replacement data was obtained by analyzing the as constructed data and corroborating it with the contract variations register.

Table 6.1: Cost Comparison of Constructed Pavements

	Location	Cost	Area	Cost/m2	Cost/m2 2019	Unsuitable subgrade
Hervey Bay	Main St	$ 1,741,403.23	11545	$ 150.84	$ 180.70	9%
	South Doolong Rd	$ 782,196.00	9595	$ 81.52	$ 88.48	22%
	Oleander Ave	$ 531,274.81	5100	$ 104.17	$ 109.97	0%
	Chapel Rd	$ 991,084.16	12035	$ 82.35	$ 86.94	8%
Maryborough	Amity St	$ 275,130.00	2337	$ 117.73	$ 125.88	37%
	Yerra Rd	$ 319,438.64	5690	$ 56.14	$ 60.02	10%
	Ward St	$ 258,454.44	2076	$ 124.51	$ 131.13	0%
	Beaver Rock Rd	$ 498,050.05	8280	$ 60.15	$ 63.50	56%

The above table reveals that the constructed pavement at Yerra Road was the cheapest on a square meter basis while Main Street was the most expensive. These pavement were both unbound granular and the investigation found that these roads were the two worst performers. In fact, Main St was the worst performing pavement, as indicated in table 6.1, meaning that the project represents the worst value for money to the Fraser Coast rate payers. Meanwhile, South Doolong Road, another unbound granular pavement, was revealed to be one of the best performing roads with the 4th lowest price. A thorough inspection of the project costs revealed that significant unsuitable subgrade was removed and replaced with a rock mattress. However, even when 22% of the cost can be attributed to the subgrade replacement, it still presents a competitive price point.

The investigation has found that generally unbound granular pavements constructed in high traffic or high HV areas, generally weren't performing to expectation. Those which were found to be performing adequately had extensive mechanic subgrade replacement undertaken, effectively increasing the total pavement depth.

It should be noted that from the investigations undertaken in Chapter 5, it is clear that in most cases the construction methodology was unchanged from project to project. Furthermore, where pavements have been constructed on expansive soil, it is expected that this has had a negative impact on the performance.

Table 6.2 displays the assumed traffic growth obtained from the design and the actual traffic growth as revealed by the latest data obtained from FCRC.

Table 6.2: Traffic Growth Rates

	Location	**Design Traffic Growth**	**Actual Traffic Growth**
Hervey Bay	Main St	4.50%	4.22%
	Chapel Rd	3.00%	13.50%
	South Doolong Rd	3.00%	18.38%
	Oleander Ave	4.00%	1.59%
Maryborough	Amity St	Data not available	Data not available
	Yerra Rd	1.00%	-2%
	Beaver Rock Rd	3.00%	-1.33%
	Ward St	Data not available	Data not available

As can be seen from table 6.2, the rate of traffic growth in all locations (where data is available) was not accurately assumed. Evidently, the growth of the region appears to be vastly different to the assumptions made by FCRC. The actual traffic growth at Chapel Road and South Doolong Road was found to be significantly larger than assumed. These large figures appear to be anomalies likely caused by incorrect traffic counts in the first instance, leading to an artificially inflated growth factor. Traffic data is a major input parameter in the design phase of a road pavement and the failure to accurately capture growth of the region can be seen to be a major contributing factor to a road pavement not performing to expectations. Amity Street and Ward Street did not have available traffic data.

Chapter 7 - Alternative Designs

In order to thoroughly evaluate and determine the most suitable pavement profiles for the Fraser Coast geology, a selection of alternative designs must be considered. As such, 3 alternative pavement profiles were analysed through a life cycle costs analysis to examine their suitability and benefit to the Fraser Coast rate payer. The following pavement types were used:

- 1 × unbound granular
- 1 × modified granular
- 1 × concrete

These three pavement types are important to analyse as they consist of materials which are readily available and of high quality in the Fraser Coast. The investigation in Chapter 5 forms the basis of this analysis with the traffic and geotechnical data used as a guide to create models which represent Fraser Coast conditions.

It was found during the investigation that the minimum subgrade CBR value in both population centres of Maryborough and Hervey Bay was 2%. Therefore, in order to utilise an acceptable subgrade CBR value, the value of 2% was used. Meanwhile, the traffic volumes were found to range from 129 AADT to 13,241 with heavy vehicle proportions of 4.3% to 26%. The traffic growth factors ranged from -2% to 18.38% and as such an average of those factors was used for the analysis. The analysis was undertaken to consider the optimum pavement profile for a low order and high order road based on the traffic data obtained from FCRC. The following design data was used:

High Order Road

- 2% CBR subgrade
- 20 year design life
- 7% annual growth
- 5000 AADT
- 10% Heavy vehicles

Low Order Road

- 2% CBR subgrade
- 20 year design life
- 7% annual growth
- 200 AADT
- 3% Heavy vehicles

CIRCLY 7.0 was used to model the three pavement options under these traffic and subgrade conditions in order to determine the optimum layer thicknesses by selecting the thickness when the cumulative damage factor (CGF) is close to but not more than 1.0. With these pavement thicknesses, the initial cost to construct each of the pavement profiles was determined using average unit rates found in Chapter 5 and the LCCA was undertaken. All pavement profiles were analysed using a bitumen surfacing, rather than asphalt since spray seals were found to be more common in the Fraser Coast. For modelling purposes, a spray seal in CIRCLY is considered to have nil thickness.

CIRCLY requires a cumulative heavy vehicle axle group (N_{dt}) input which is calculated using equation 3.2 (calculations found in Appendix E):

CIRCLY 7.0 includes all of the load distributions (TLDs) which are included in AGPT02 (2017) to allow for accurate modelling, however there is no TLD that represents the traffic conditions of the Fraser Coast. Discussions with FCRC's design department revealed that their designers use the example TLD provided in CIRCLY as they believe it offers a good spread of vehicle axle groups. Therefore, the example TLD was used for this analysis.

DTMR recommends that pavement layers typically should not exceed 250mm to allow for proper compaction of the material, however this can be relaxed where for instances such as where pavement must match kerb and channel profiles. For the purposes of this analysis, all pavement layers were kept to a maximum of 250mm in accordance with DTMR standards (DTMR, 2020). The chosen pavement thicknesses were also selected in increments of 5mm to allow for practicality in construction.

7.1 CIRCLY Analysis

7.1.1 Unbound Granular Pavement Design

The unbound granular pavement design was designed to use materials which are readily available in the region and is of a similar profile to many pavements which are constructed within the Fraser Coast. DTMR's supplement to AGPT02 suggests that unbound granular materials type 2.1 should be modelled with a modulus value of 350MPa when used as a base course. Meanwhile, type 2.3 should be modelled with a modulus of 150MPa when used as a subbase course (DTMR, 2018). The following pavement structure was adopted:

- Surfacing — C170 14/7mm double/double seal
- Base course — Type 2.1 (Min CBR > 80%)
- Subbase course — Type 2.3 (Min CBR > 45%)

The CIRCLY analysis revealed that to achieve a CDF value of near 1, a pavement structure of 510mm depth was required on the low order road, as illustrated in Figure 7.1.

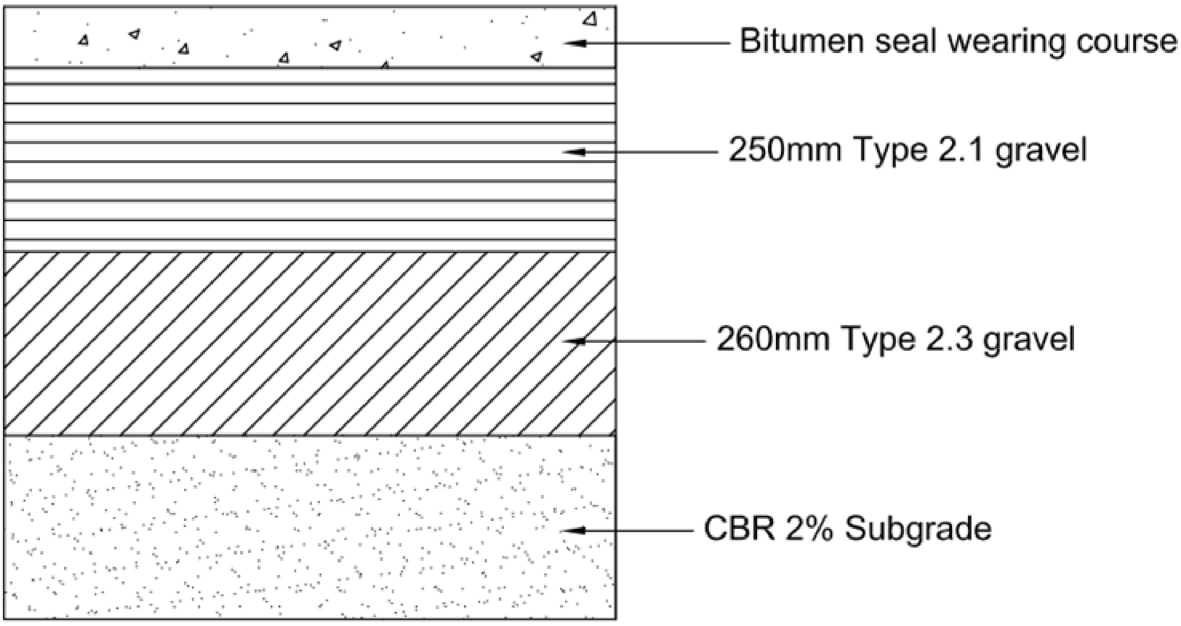

Figure 7.1: Unbound Granular Pavement – Low Order Road

The analysis for the high order road revealed that the assumed pavement structure was not appropriate and to meet the maximum 250mm thickness requirement. Therefore, a lower subbase of type 2.3 gravel is included, making the total pavement depth 730mm, as indicated in figure 7.2.

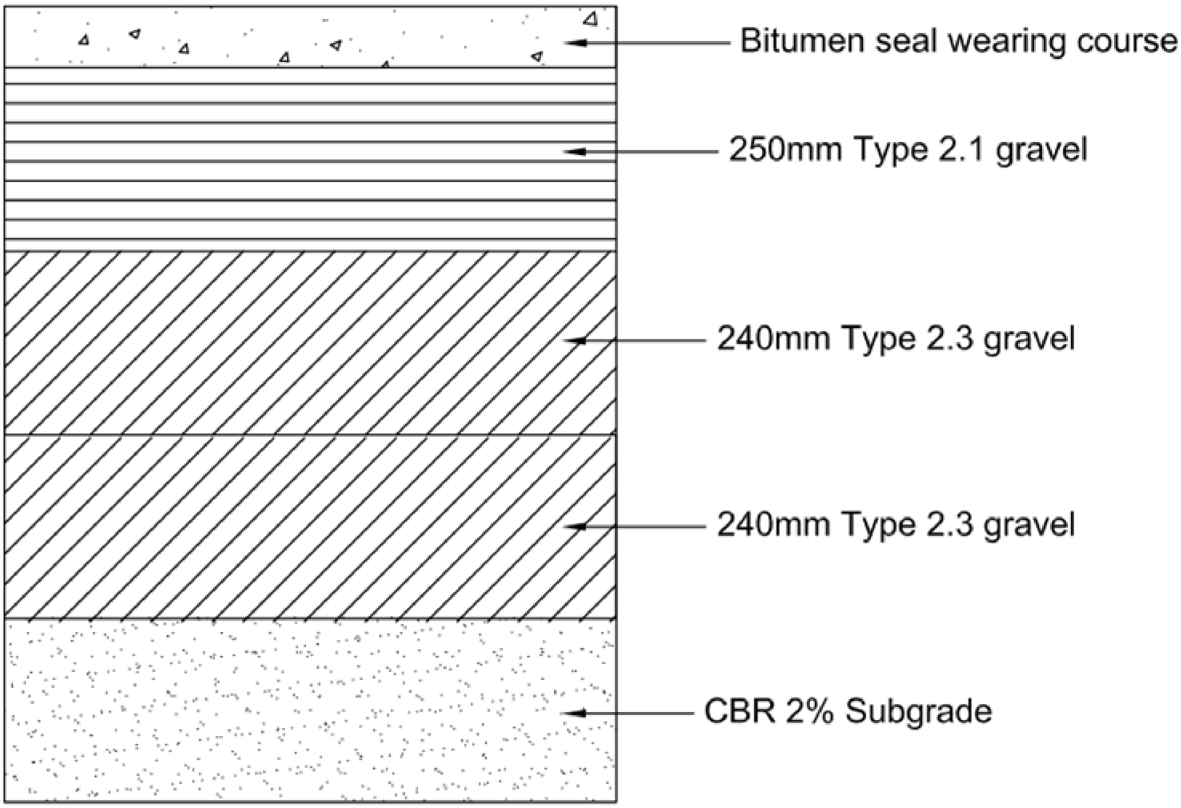

Figure 7.2: Unbound Granular Pavement – High Order Road

7.1.2 Modified Granular Pavement Design

The modified granular pavement was designed to use materials which are readily available in the region and is a variation of the unbound granular pavement above. DTMR's supplement to AGPT02 suggests that lightly modified granular materials may be modelled as post-cracked with a modulus of 500MPa (DTMR, 2018). The reasoning for this is that lightly bound pavement materials are likely to become cracked under construction traffic. The following pavement structure was adopted:

- Surfacing — C170 14/7mm double/double seal
- Base course — Type 2.1 (Min CBR > 80%)
- Subbase course — Type 2.3 CTB UCS 2.0 (Min CBR > 45%)

The CIRCLY analysis revealed that to achieve a CDF value of near 1, a pavement structure of 310mm depth was required for the low order road, as illustrated in Figure 7.3.

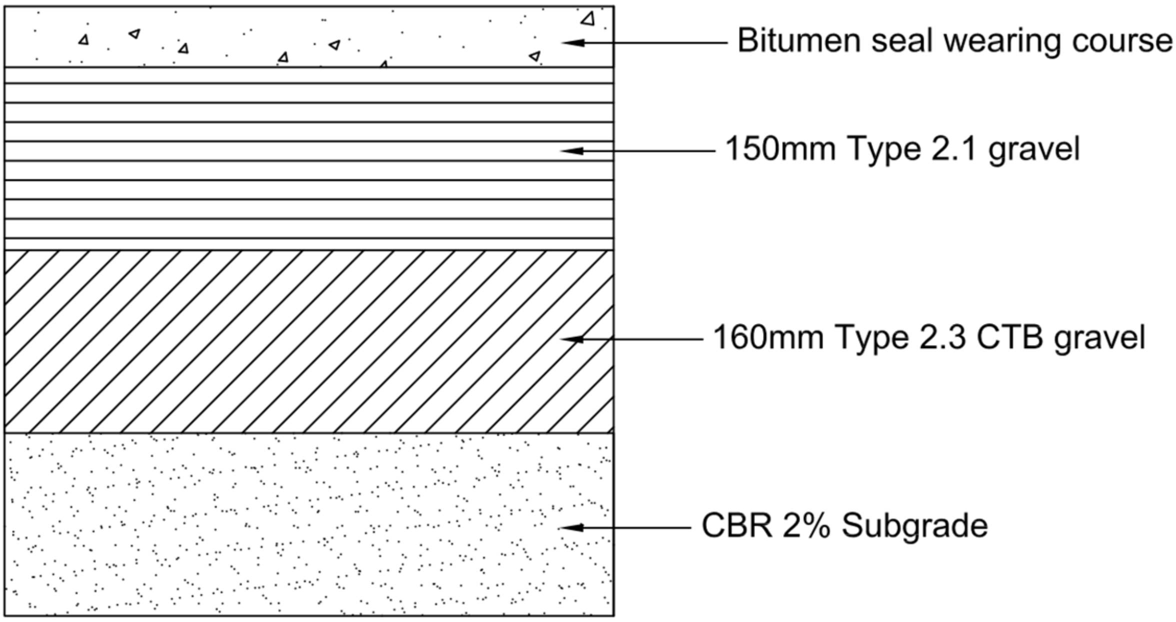

Figure 7.3: Modified Granular Pavement – Low Order Road

The CIRCLY analysis of the modified pavement for the high order road required the pavement structure to be of 480mm depth, as illustrated in Figure 7.4.

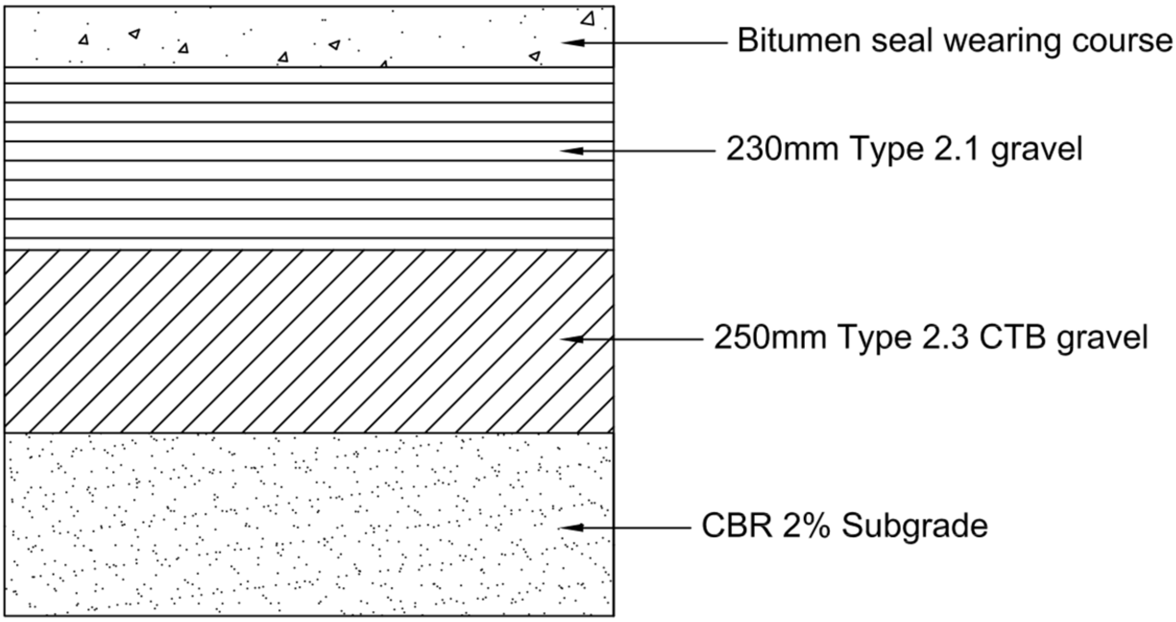

Figure 7.4: Modified Granular Pavement: High Order Road

7.1.3 Concrete Pavement Design

The concrete pavement was designed to use materials which are readily available in the region and is a different treatment to what has been used in the Fraser Coast in the past. The design calls for an unbound granular base course with a lean-mix (LCS) subbase to bridge the subgrade and reduce the overall pavement thickness. DTMR's supplement to AGPT02 suggests that LCS must have a minimum thickness of 150mm on low CBR subgrade (DTMR, 2020). Furthermore, the NSW Roads and Maritime Service supplement to AGPT02 writes that a lean mix subbase must satisfy a modulus of 10,000MPa (RMS, 2018). The following pavement structure was adopted:

• Surfacing	AMC00 Prime S45R 14/7mm double/double seal
• Base course	Type 2.1 (Min CBR > 80%)
• Subbase course	Lean-mix (LCS)

The CIRCLY analysis revealed that to achieve a CDF value of near 1, a pavement structure of 325mm depth was required on the low order road, as illustrated in Figure 7.5.

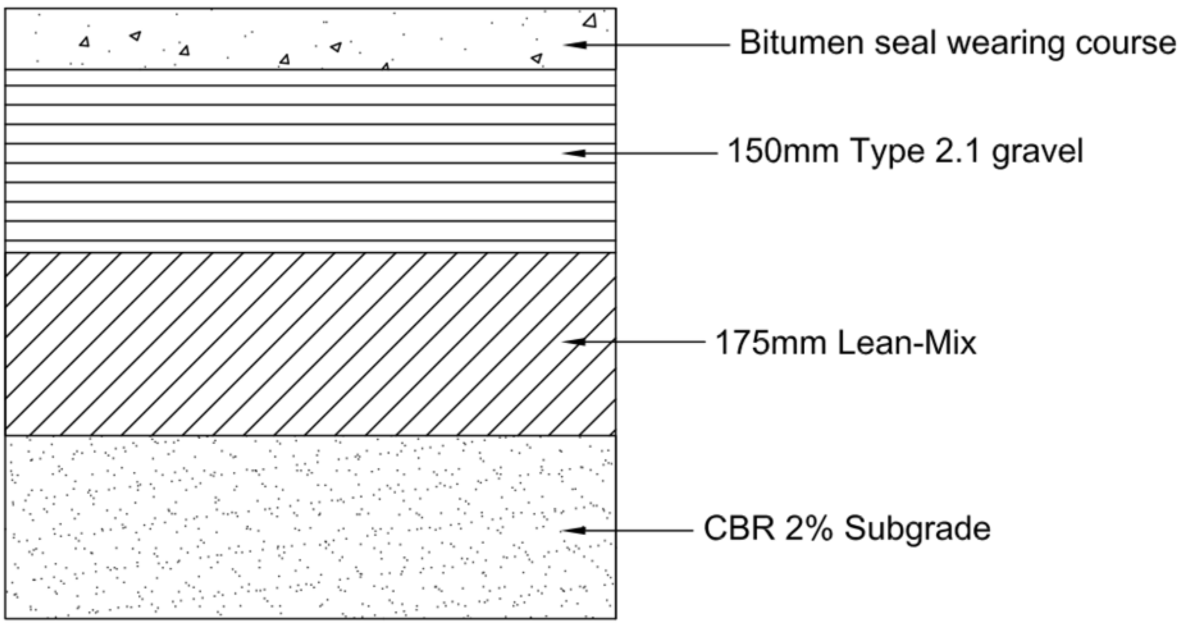

Figure 7.5: Concrete Pavement: Low Order Road

The CIRCLY analysis of the modified pavement for the high order road required the pavement structure of 420mm, as illustrated in Figure 7.6.

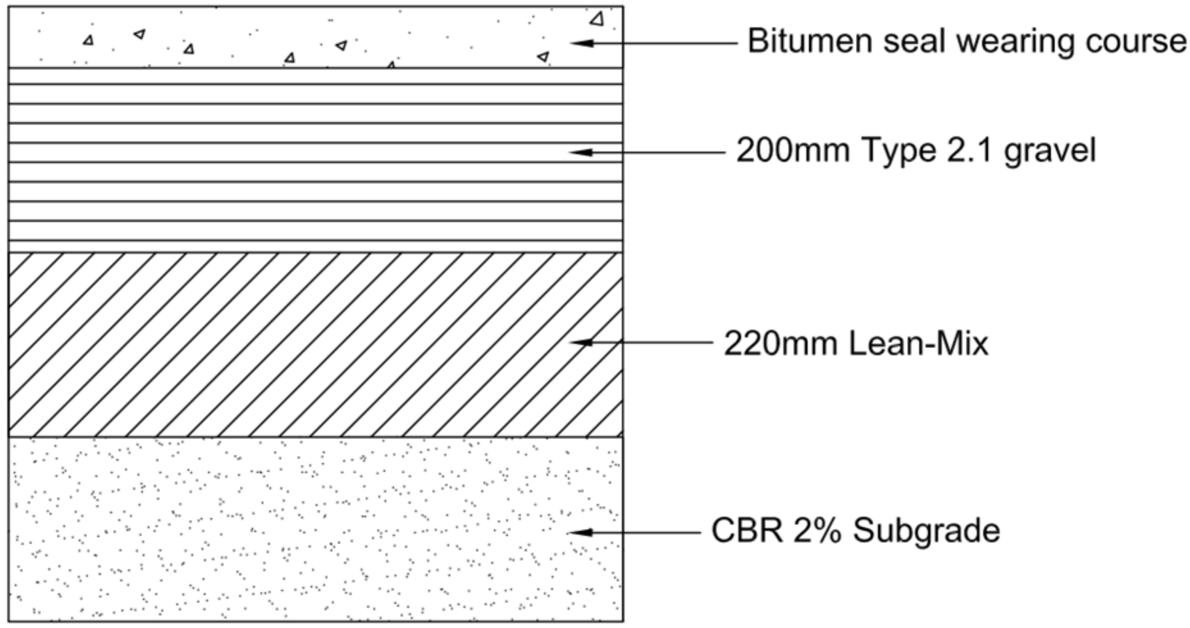

Figure 7.6: Concrete Pavement: High Order Road

7.2 Life Cycle Cost Analysis

The life cycle cost analysis (LCCA) considered the initial costs borne to construct each of the proposed alternative designs on a square metre basis as well as the expected ongoing maintenance costs. The present worth of costs (PWOC) method was used to determine the most cost effective option over the analysis period.

The U.S. Department of Transportation (2002) wrote that when conducting an LCCA, alternatives must be evaluated over an equivalent analysis period to yield a fair result. Furthermore, alternative with a service life in excess of the analysis period must be adequately accounted for by considering the remaining service life as a percentage of the analysis period (USDT, 2002). For the purpose of this project, the analysis period is 20 years.

7.2.1 Initial Cost

As a means of considering the costs borne to construct the alterative designs, the unit rates from the investigated roads were adjusted for inflation and averaged to determine the present value. Since appropriate rates for LCS could not be found based on historical FCRC data, Rawlinsons Construction Cost Guide 2016 was used to determine a value based on a indexed value in Maryborough. Table 7.1 displays the unit rates used for this analysis.

Table 7.1: Construction Rates

Material	Unit	Rate
Type 2.1	m3	$ 103.35
Type 2.3	m3	$ 83.37
Type 2.3 CTB	m3	$ 153.27
Concrete (leanmix)	m3	$ 250.38
14mm aggregate	m3	$ 230.42
7mm aggregate	m3	$ 247.49
AMC00 prime	L	$ 1.58
C170 Binder	L	$ 1.80
S35E Binder	L	$ 1.84

Table 7.2 represents the initial cost calculations for each pavement profile on a square metre basis. A breakdown of the cost calculation may be found in the appendix. In order to determine the quantities of bitumen and aggregate for each of the roads, a spray seal design was undertaken for the traffic conditions of the low order and high order roads. This design uses an assumed aggregate ALD and can also be found in the appendix.

Table 7.2: Initial Construction Costs

Pavement Type	Low Order Road (cost/m2)	High Order Road (cost/m2)
Pavement Option 1 - Unbound Granular	$ 64.69	$ 86.50
Pavement Option 2 - Modified Granular	$ 53.31	$ 77.96
Pavement Option 3 - Concrete	$ 73.72	$ 91.17

7.2.2 Maintenance Schedule

One of the most critical aspects of road asset management is a rigorous maintenance schedule which ensures that the road is as function as when it was first constructed. Only with such maintenance can a constructed pavement be expected to reach its service life and not fall below the minimum level of service expected by the community (AGPT07, 2009).

Since each of these roads are modelled with bitumen surfacing, they will have similar maintenance schedules to ensure adequate service. Indeed, a bitumen reseal is considered to be the single most important element of maintenance required and involves a single layer of bitumen and a single layer of aggregate. The rates for resealing were determined by taking inflation adjusted averages from the previous 3 years of resealing contracts at FCRC. Table 7.3 displays the adjusted rates for different aggregates and binders.

Table 7.3: Resealing Rates

Item	Unit	Rate
C170	L	$ 1.37
S45R	L	$ 1.37
7mm	m3	$ 173.98
10mm	m3	$ 173.98
14mm	m3	$ 185.66

Table 7.3 represents the maintenance costs to reseal the surface of each pavement at 10 year intervals over the analysis period.

Table 7.4: Maintenance Costs

Pavement Type	Low Order Road (cost/m2)		High Order Road (cost/m2)	
	10 year reseal	20 year reseal	10 year reseal	20 year reseal
Pavement Option 1 - Unbound Granular	$ 7.25	$ 7.25	$ 6.53	$ 6.53
Pavement Option 2 - Modified Granular	$ 7.25	$ 7.25	$ 6.53	$ 6.53
Pavement Option 3 - Concrete	$ 7.34	$ 7.34	$ 6.61	$ 6.61

7.2.3 Present Worth of Costs

Austroads guide to pavement technology part 2: pavement Structural Design suggests the best method to compare the whole of life costs revealed during the LCCA is with the present worth of costs calculation:

$$PWOC = C + \sum_{i} M_i(1+r)^{-xi} - S(1+r)^{-z}$$

Where:

$PWOC =$ Present worth of costs

$C =$ Present cost of initial construction

$M_i =$ Cost of the i^{th} maintenance measure

$r =$ Real discount rate

$x_i =$ Number of years from the present to the i^{th} maintenance measure within the analysis period.

$Z =$ Analysis period

$S =$ Salvage value of pavement at end of the analysis period

The following tables display the PWOC calculations for the unbound, modified and concrete pavement structures. A breakdown of the calculation may be found in the appendix. The real discount rate adopted was 7% as suggested by Infrastructure Australia as the most suitable rate for public sector project analysis. However, rates of 4% and 10% were also used for the purposes of a sensitivity analysis to observe any change in outcomes. (AGPT02, 2017). Furthermore, since the pavements are constructed with bituminous surfacing rather than asphalt, the salvage value is assumed to be nil for all pavement options.

Table 7.5: Present Worth of Cost Calculations Iteration 1

r = 4%		
Pavement Type	**Low Order Road (PWOC)**	**High Order Road (PWOC)**
Pavement Option 1 - Unbound Granular	$ 68.00	$ 89.48
Pavement Option 2 - Modified Granular	$ 56.62	$ 80.94
Pavement Option 3 - Concrete	$ 77.07	$ 94.18

Table 7.6: Present Worth of Cost Calculations Iteration 2

r = 7%		
Pavement Type	**Low Order Road (PWOC)**	**High Order Road (PWOC)**
Pavement Option 1 - Unbound Granular	$ 66.56	$ 88.18
Pavement Option 2 - Modified Granular	$ 55.18	$ 79.65
Pavement Option 3 - Concrete	$ 75.62	$ 92.88

Table 7.7: Present Worth of Cost Calculations Iteration 3

r = 10%		
Pavement Type	**Low Order Road (PWOC)**	**High Order Road (PWOC)**
Pavement Option 1 - Unbound Granular	$ 65.77	$ 87.47
Pavement Option 2 - Modified Granular	$ 54.38	$ 78.93
Pavement Option 3 - Concrete	$ 74.81	$ 92.15

Evidently, it can be seen from the above tables that the modified granular pavement structure offers the most value for money to FCRC over the analysis period of 20 years. The sensitivity analysis has demonstrated that the outcome does not change with varying discount rates. This is due to the cost of materials available in the region and the shallow pavement depths required to construct this option.

Chapter 8 - Discussion

8.1 Site Investigation

The investigation undertaken in Chapter 5 explored the road reconstruction practices used at FCRC over 8 different locations between Hervey Bay and Maryborough. All locations revealed very low CBR subgrade material with evidence of expansive clay at some sites, proving to be a difficult platform to build upon.

The available designs were checked using the Austroads design charts in Figure 3.10, Figure 3.11 and the original input data to check their appropriateness to the situation. In most instances, the designs were found to be adequate for the input parameters. Further to this, an alternative design was undertaken using the same pavement configuration but with the actual traffic data obtained from FCRC to consider the effectiveness of the design. It was found in some instances that the pavement would have benefited from a deeper thickness. However, the failures and distress modes identified at all locations cannot be attributed to this factor. In fact, in some cases where the pavement was found to be sufficient, there was still evidence of some failures or excess wearing, indicating an extraneous issue.

The design checks have indicated that the design process used at FCRC is sound but some assumptions fed into the process require further due diligence. Indeed, ensuring the input parameters are correct is a fundamental aspect of constructing a pavement which will reach its design life.

The investigation has also indicated that in most cases, the designs were not the cause of failure, but rather it is possible the problem lies in construction. It can be difficult to pinpoint exactly which element in the construction process is at fault. It may be the methodology or the quality of materials used. This highlights the importance of undertaking audit testing of material stockpiles to confirm their conformance to specifications. Also, the importance of quality testing the product by means of compaction, level conformance, as well as on site checks to ensure full functionality of components such as subsoil drainage. Furthermore, where pavements have been constructed on high plasticity soil, there is a high expansive potential which is also a factor contributing to pavement distress in the Fraser Coast.

It should be recognised that there are a number of different modulus values which designers could have reasonably assigned to various pavement materials when using CIRCLY. Where

CIRCLY was used in this analysis, all modulus values were chosen in accordance with relevant standards and specifications, however the accuracy of results cannot be totally determined.

The most recent available traffic count data obtained from FCRC was compared to the design traffic counts and growth assumptions to evaluate its accuracy. As suggested in Chapter 6, the traffic growth assumptions were found to be incorrect in all instances. However, for the locations that demonstrated the highest growth rates, it is expected that these are not accurate and may be arterially inflated due to distorted data. Indeed, this is likely caused by incorrect traffic counts in the first instance. It is imperative to ensure that this design parameter is correct as the entire design process hinges on it and it can have a significant impact on the required pavement depth.

The only available condition data in FCRC's records that could be used for this project was the laser profilometer data from 2017, limiting the window for which year's road reconstructions could be investigated. The condition data was considered to be the single most important piece of information as it allowed the site investigation to be benchmarked against a historical evaluation to be able to consider the performance of the pavement. If more data was available from FCRC then a more comprehensive and potentially more accurate evaluation could have been undertaken which explores the performance of the pavements over several years. Indeed, it would be beneficial for FCRC to undertake condition testing at regular intervals, perhaps every 12 or 24 months to create a data set which can be used to monitor the performance of the road network over time. This would be an extremely valuable tool to allow staff to try different pavement structures and examine the constructed pavement to consider their performance and inclusion in future designs. This data would also feed directly into the road resurfacing and rehabilitation programmes.

The investigation in Chapter 5 found that some of the geotechnical investigations clearly did not reveal the full extent of the subgrade conditions due to the extensive amounts of money spent to mechanically replace subgrade at an extra cost to the project budgets. Furthermore, it is shown that some of the pavements experiencing failure which have been appropriately designed are constructed on expansive clays. If the geotechnical investigations were more conclusive, then the pavement structures may have varied and resulted in higher BOQ quantities in the tender but this would have been priced by the whole market, not just the one contractor who won the project. Therefore, while the contract value may have been higher, the overall cost may be reduced since there would be no variation work undertaken for subgrade treatment. As such, it would be beneficial if more detailed investigations were undertaken including the use of test pits in lieu of bore holes. It is acknowledged that test pits will incur a significantly higher cost and increased disruption to traffic so it should only be provided for where circumstances allow.

8.2 Economic Comparison

Rates provided by contractors at the tender stage depend greatly on the availability of resources, location, quantity of work available in the region and skill level required. The economic comparison of the as constructed projects was undertaken by comparing the prices of the contracts on a square metre basis. There was no consistency found in the pricing and no correlation found between prices and performance. This was an interesting result and it confirmed the notion that the Fraser Coast is subject to large changes in pricing due to factors which are out of the control of the council. However, it is recognised that a square metre cost comparison doesn’t capture fluctuations in prices due to market competition, availability of resources or economic climate. It also doesn’t capture the intricacies of each project such as the extent of underground services, existing infrastructure to match into or traffic considerations.

The cost comparison revealed that the construction of Main St was the highest while it was found to be the worst performing pavement with extensive failures and surface distress. Meanwhile, Yerra Road was found to be the cheapest which was the second worst performing pavement with significant deformation and rutting for its age. This not only demonstrates the lack of a relationship between price and quality but also demonstrates the large spread of square meter prices to construct unbound granular pavements in the Fraser Coast.

8.3 Life Cycle Cost Analysis

The LCCA was undertaken to determine the most suitable pavement profile of use in the Fraser Coast by modelling two different scenarios: a high order road and a low order road using traffic and geotechnical data from chapter 5 as a guide.

The LCCA suggested the modified granular pavement with lightly bound CTB subbase and granular base course represented the most value in both of the modelled situations. A sensitivity analysis was undertaken with a range of real discount rates to observe if the outcome was affected. It was confirmed that the outcome remained the same regardless of the real discount rate. The difference in value between the pavement options was consistent over each of the situations where the modified pavement was the cheapest, followed by the unbound and finally the concrete option. Consideration must be given to the cost difference between the unbound and modified pavement options on low order roads. Indeed, while the modified option may have a lower overall cost, the unbound option may be favoured due to the simplified construction methodology and duration which can be applied to the project. Meanwhile, the modified option does require extra construction time due to curing of the cemented material. The unbound granular option offers the least disruption to residents and traffic of the three options and may be preferred when working in residential areas where disturbance to locals is of paramount concern.

The depth of excavation required to construct the unbound granular pavement on the high order road was considerably more than the other two options, however it was still not the most expensive option. The pavement depth required in this model further supports the observations from the design checks that some pavements constructed were designed with insufficient depth. Indeed, the LCCA revealed that unbound granular pavements are not the most practical option for high traffic roads, whereas modified or concrete pavements provide a more advantageous choice.

Pavement option 3: concrete pavement was demonstrated to be the least cost effective in both scenarios due to the high rate for the LCS subbase. Due to the amount of rainfall in the Fraser Cost, subsoil drainage is essential for any pavement to ensure adequate performance. It should be noted that the LCS may provide an advantage over the two granular options in locations where subsoil drainage cannot be installed due to the absence of appropriate outlet points. In these circumstances, the LCS would provide adequate support for the granular base material and would not degrade or deform when the subgrade becomes saturated.

While the results of this investigation should prove useful, it is important to consider there are numerous conditions which can influence the type of pavement which should be selected. Indeed, it may be found that on higher quality subgrade material, the unbound pavement offers the most value for money over the life cycle to the lower material cost and the inherent shallower excavation. It is also important to note that the availability of rates from FCRC contracts for lean-mix concrete was limited as it is an uncommon material for use in the Fraser Coast. Subsequently, the rate was determined using Rawlinson’s Construction Cost Guide 2016 meaning that the ultimate cost analysis of the LCS option may not be as accurate as the other options. As revealed in this project, some roads in the Fraser Coast are constructed on expansive soils which has had a negative effect on the pavement structure. While this analysis involved examining pavement performance on CBR 2% subgrade, it does not consider how to mitigate the effects of expansive soils on pavements and further research should be conducted into the topic.

This analysis can be considered to be a worst case scenario due to the very low subgrade material being some of the worst that can be found in the region, although it is widely spread. Nevertheless, along the coastline the subgrade can be found to be dense sand with CBR values ranging from 10-15% and in some locations rock can be found. Undeniably, the task of determining the most suitable pavement profile to use in the Fraser Coast has proven to be extremely complex with a wide range of factors requiring consideration. Therefore, it must be stated that determining one single profile is not an achievable task as some pavements are more suited to different circumstances.

Chapter 9 - Recommendations and Conclusions

9.1 Recommendations

As a result of the research and investigations carried out as part of this project, the following recommendations are made to the Fraser Coast Regional Council to improve their road reconstruction practices:

- Correctly assumed design input parameters are imperative to any project as it forms the foundation of the design. Traffic counts and growth assumptions should be accurate and carefully consider future growth and development. It is important to ensure that the predicted growth of the region is correct in order to design and construct pavements which will be high performing and serve the community until the end of their life cycle.

- Up to date and regularly collated condition data is important to provide an accurate understanding and allow close monitoring of pavement performance across the region. Therefore, condition testing should be undertaken more regularly to create a data set which allows staff to monitor the performance of the network and methodically plan for maintenance and rehabilitation treatments.

- It was revealed throughout the investigation that many projects required extensive subgrade replacement due to the presence of unsuitable material. In many cases, this significantly increased the project costs and duration. Hence, it is recommended that FCRC undertake more comprehensive geotechnical investigations to accurately identify subgrade conditions over the whole project which will allow for a more suitably designed pavement structure. In situations where expansive soil is present, subgrade treatment should be applied which can mitigate the expansive potential of the soil, ultimately protecting the pavement structure.

- Throughout the research and investigation of various roads which have been reconstructed by FCRC, it was noted that there is a limited range of different treatments and pavement profiles used. As such, further investigation should be undertaken by FCRC into alternative pavement rehabilitation treatments and pavement profiles.

- Record keeping is an essential practice which allows an organisation to revisit past projects and gain a detailed understanding events down to fine detail. In some instances, it was found that throughout the investigation that all records were not available due to inconsistent record keeping practices. Therefore, it is recommended that some focus be placed on record keeping for FCRC projects to allow for future staff to understand all details of past projects in order ensure continual improvement of construction practices.

- The modified granular pavement profile was found to be the most beneficial to the Fraser Coast community as a result of the LCCA. FCRC has demonstrated use of similar profiles in the past and should continue to use it into the future. It should be noted that this recommendation is made on the assumption that a proper maintenance schedule will be followed.

9.2 Further Research

It is important to continually improve pavement reconstruction practices by considering further improvements and development which could be included. The following items are suggested as being in the interest of improving the pavement reconstruction practices at FCRC:

- As the world moves toward more sustainable means of living, it is important to ensure that the construction industry and particularly local government is contributing to a greener future. As such, it would be beneficial to conduct further research into the use and performance of recycled materials in council road pavements including crushed glass, crushed concrete, plastic and recycled asphalt pavements (RAP).

- Since the modified granular pavement was found to be the most effective in both circumstances, it would be beneficial to conduct further research into similar pavements including those modified with other materials such as lime or bitumen to see how they would perform in the Fraser Coast.

- The Lean-mix subbase pavement option was found to be the most expensive over its lifecycle in both modelled scenarios. It would prove useful to seek quotes from Fraser Coast contractors to construct a pavement with LCS subbase to obtain rates in order to conduct a more accurate cost analysis of the LCS subbase pavement option.

- This research project intended to create a flow chart to allow staff at FCRC to select the most suitable pavement structure for given geological and traffic conditions. However, due to time restrains, this has not eventuated. As such, further time should be devoted to creating this flow chart to aid in design selection at FCRC.

9.3 Conclusion

The primary aim of this project was to critically evaluate the current pavement reconstruction practices used at the Fraser Coast Regional Council and consider the most appropriate pavement profiles to use in the region. It was found that FCRC's practices are generally sound and had been effective in some instances while others had demonstrated deficiencies. The design checks revealed that the original pavement designs were generally adequate and as such the design practices at FCRC are sound. However, the effectiveness of particular pavement profiles is case specific and largely depends on correct design parameters. It must be noted that since this project evaluated 8 roads, it is not an all-encompassing review of the effectives of FCRC's techniques.

The LCCA conducted as part of this research project yielded results which should prove to be valuable to FCRC by ensuring that the most cost effective pavement option is chosen over the road's life cycle. Indeed, due to the low population density of the Fraser Coast, it is imperative to provide the rate payers of the Fraser Coast with roads that can be sustained with a simple maintenance schedule in order to service the large road network.

Initially it was thought that this project could determine the most suitable and cost effective pavement profile for use in the whole region. However, through the course of this project, the complexities and intricacies of pavement design, construction and the overall variances of road design parameters has demonstrated that this was not achievable. In fact, The LCCA has established that one pavement profile is not suitable over all situations and that different pavement types are suited to different circumstances.

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Appendix A

Project Specification

<u>ENG4111/4112 Research project</u>

Project Specification

For: Kaz Chapman-Vagg

Title: Effective Road Pavement Reconstruction in Fraser Coast Region, QLD

Major: Civil Engineering

Supervisor: Andreas Nataatmadja

Enrolment: ENG4111 – ONL S1, 2020
ENG4112 – ONL S2, 2020

Project Aim: To investigate current road reconstruction methods at the Fraser Coast Regional Council and identify the optimum pavement configuration given the geological conditions and materials available in the region.

Programme: Version 2, 15th September 2020

1. Undertake a literature review to investigate current and historical information relating to the construction of road pavements in Australia. This shall include design and construction methods, subgrade treatments, pavement design life, and required materials.
2. Identify up to eight (8) roads in the Fraser Coast region which have been reconstructed within the last 10 years.
3. Obtain construction data for each road including construction drawings, as constructed data, geotechnical information, project costs, project methodology and any other data which may be relevant.
4. Evaluate existing pavement condition through non-destructive means and analyse pavement performance.
5. Compare effectiveness of as constructed pavements and conduct an economic comparison of the profiles.
6. Suggest alternative designs using methods identified in research and evaluate new pavement designs using CIRLCY.
7. Consider constructability, initial costs, duration, availability of resources and future maintenance of alternative designs in order to undertake a life cycle cost analysis.
8. Make conclusions on the most effective pavement to ensure that the Fraser Coast road network can be adequately serviced and maintained into the future.

If time permits:

9. Create flow chart to allow council to select the appropriate pavement type and structure based on location, traffic, soil conditions.

Appendix B

Site Investigation Records

Site Visit Record			
Site Name:	MAIN ST H. BAY	**Year Constructed**	2010
Weather Conditions:	FINE.	**Time:**	11am
Site Record	Traffic Conditions (Vehicle Types, volumes etc.): * HIGH VOLUMES OF TRAFFIC * SOME HEAVY VEHICLES. * KERB AND CHANNEL AND DRAINAGE STRUCTURES IN GOOD CONDITION – NO SILT OR EVIDENCE OF POOR DRAINAGE		
Identified Defects	* EXTENSIVE CROCODILE CRACKING IN WHEEL PATHS * RUTTING IN WHEEL PATHS * FLUSHING * MINIMAL PATCHING – SOME SHOVING NEAR PATCH VISUAL INSPECTION INDICATES SIGNIFICANT PORTION OF MAIN ST ~~IS~~ HAS FAILURES AND MAY NOT REACH ITS SERVICE LIFE		
Overall Pavement Condition (1=best)	1……………3……………5……………✓……7……………10 POOR		
Signature	Inspector		17/07/20 Date

PAVEMENT DEFECT MAPPING SHEET

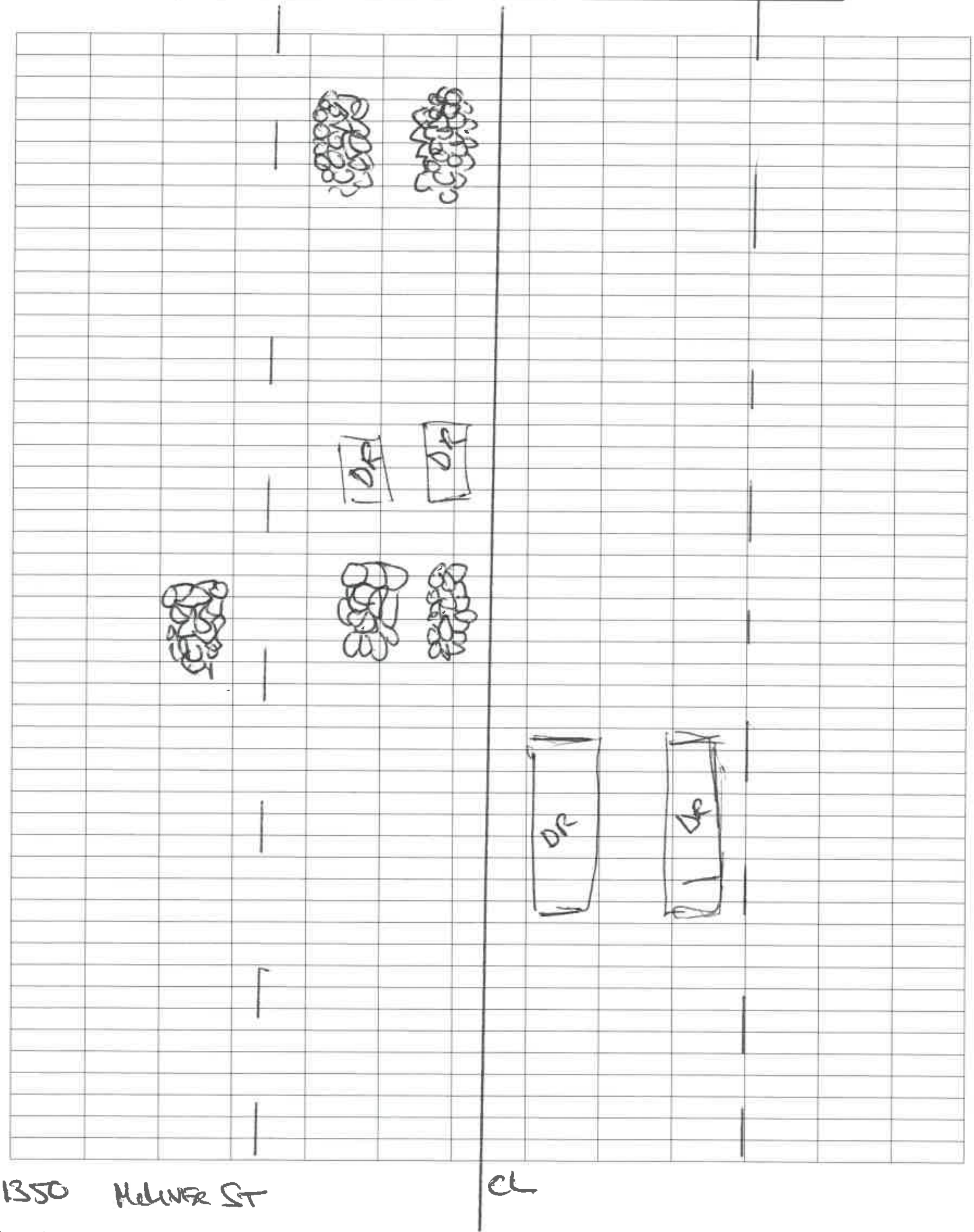
Road Name: MAIN ST H. BAY

Inspector Initials: KC

Suburb:

Description:

CH1020



CH1350 MULINER ST

CL

SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)
Crescent (shear) cracking
Block cracking
Crocodile cracking
Patching
Shoving

Source: Queensland Department of Transport and Main Roads (2006).

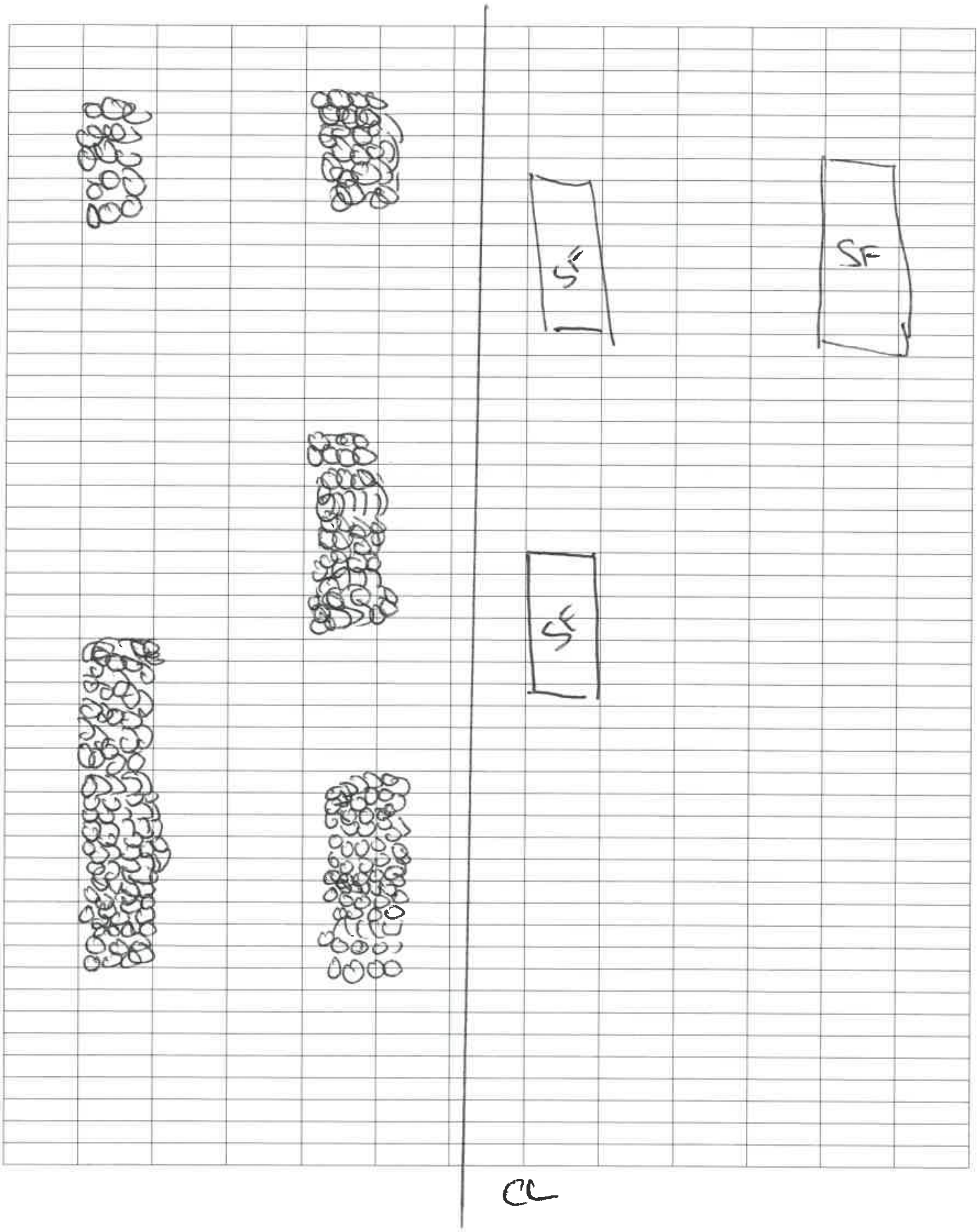
PAVEMENT DEFECT MAPPING SHEET

Road Name: MAIN ST H. BAY

Inspector Initials: KE

Suburb: ____________________

Description: ________________________________



CH 700

CL

SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

P Crack (P- pumping)

Crescent (shear) cracking

Block cracking

Crocodile cracking

Patching

Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record

Site Name:	CHAPEL ROAD HERVEY BAY	**Year Constructed**	2016
Weather Conditions:	FINE	**Time:**	2pm

Site Record

Traffic Conditions (Vehicle Types, volumes etc.):

* MEDIUM TRAFFIC VOLUME
  → NON PEAK TIME

Identified Defects

* EXTENSIVE FLUSHING IN WHEEL PATH
* SOME RUTTING
* PAVEMENT APPEARS OK BUT EXTENSIVE SURFACE DISTRESS

Overall Pavement Condition (1=best)

1..............................3..............................5..............................7..............................10

Signature

Inspector

20/08/20.

Date

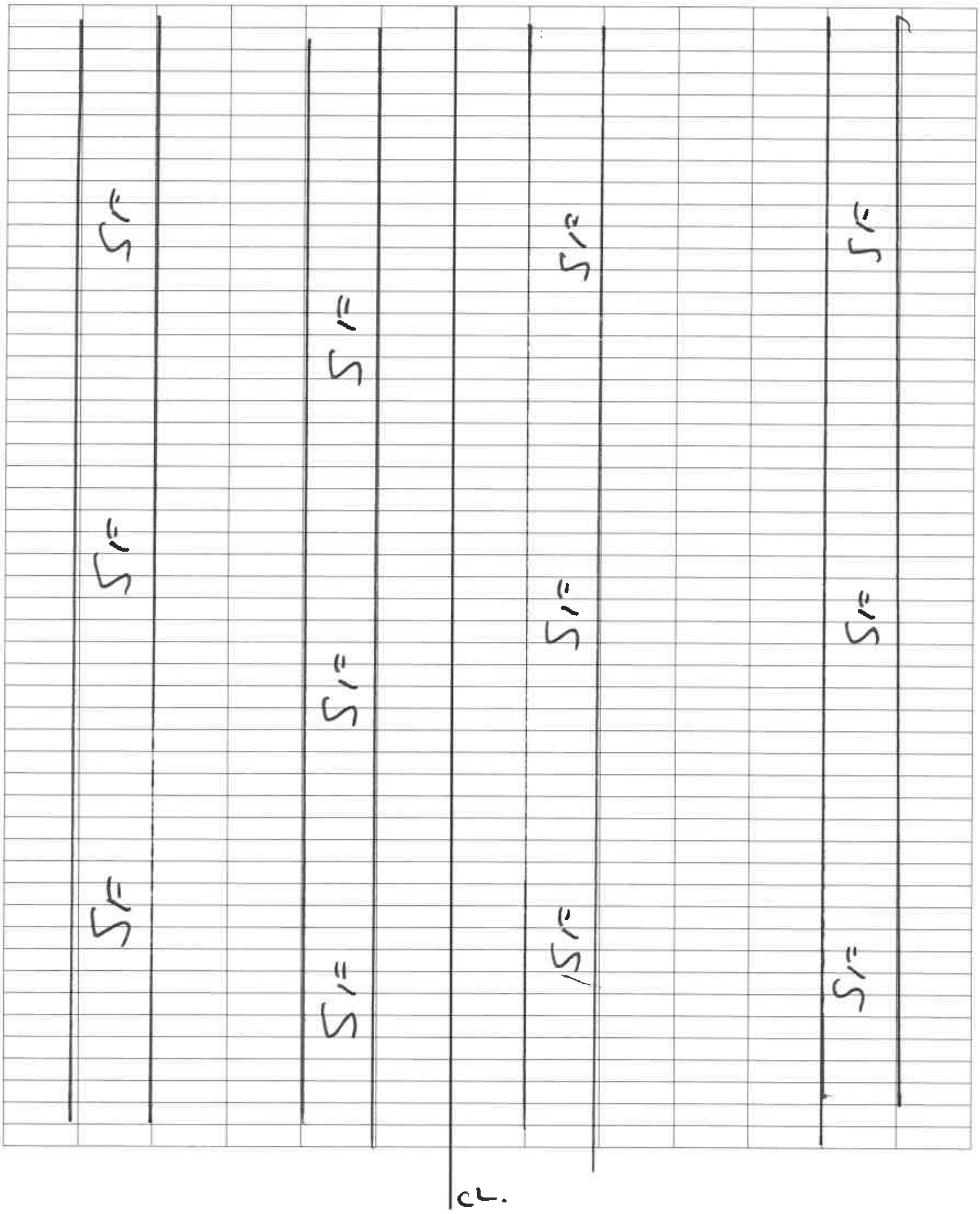
PAVEMENT DEFECT MAPPING SHEET

Road Name: CHAPEL RD H. BAY Inspector Initials: KE

Suburb: __________

Description: __________

CH 1150



CH0

SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)

Crescent (shear) cracking

Block cracking

Crocodile cracking

Patching

Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record			
Site Name:	STH DOOLONG RD	**Year Constructed**	2015
Weather Conditions:	FINE	**Time:**	10am

Site Record

Traffic Conditions (Vehicle Types, volumes etc.):

* NON PEAK TIME — LOW VEHICLE FLOW.
* LOW HEAVY VEHICLES
* FORMATION IN GOOD CONDITION.
* WATER CAN FREELY DRAIN.

Identified Defects

* FLUSHING
* MINOR RUTTING
* RAVELLING

Overall Pavement Condition (1=best)

1..................................3.................................✓...........5...7.....................................10

Signature

Inspector

24/07/20.

Date

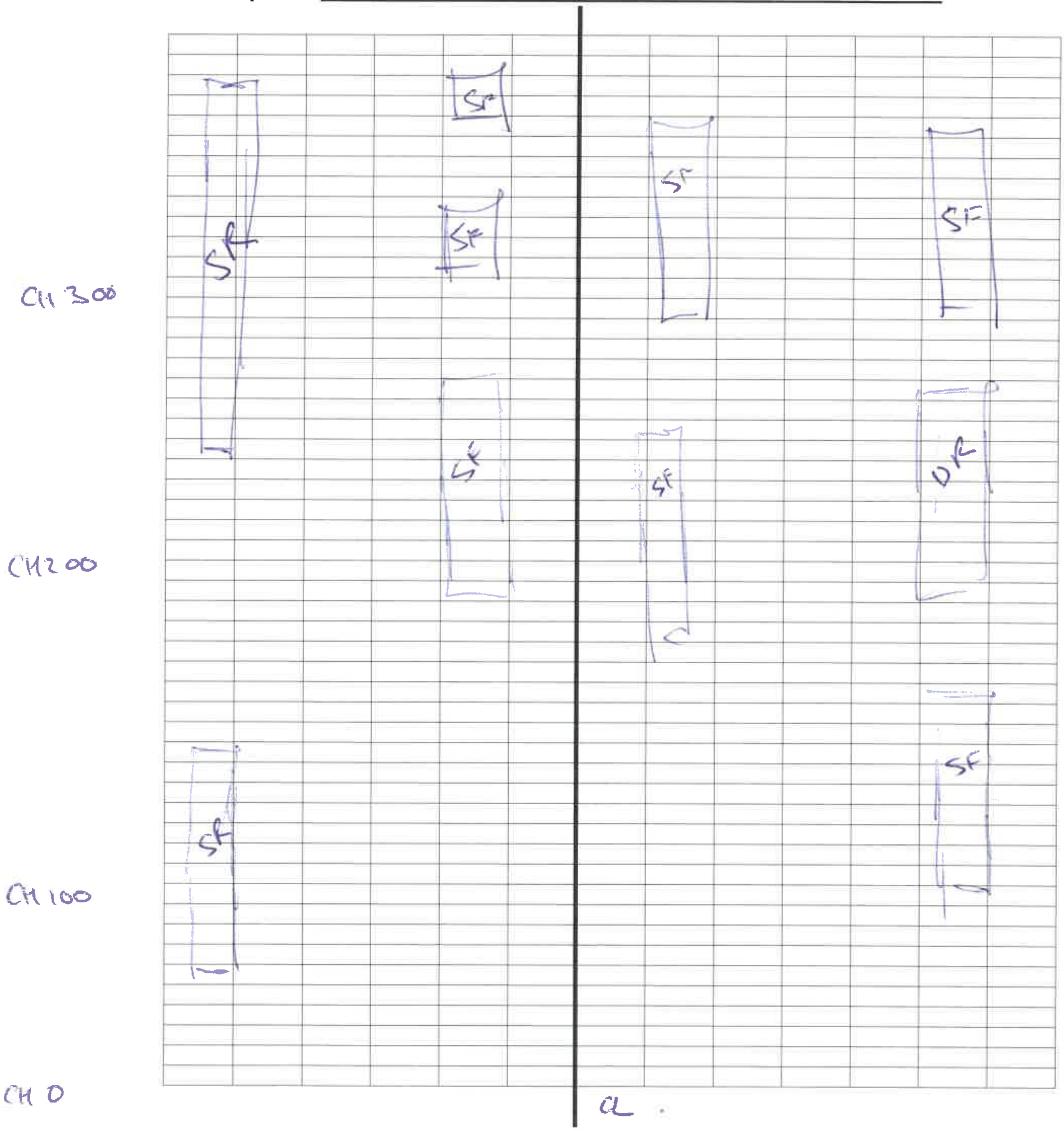
PAVEMENT DEFECT MAPPING SHEET

Road Name: Sth Doolonk

Inspector Initials: Ke

Suburb: H. BAY

Description:



SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)
Crescent (shear) cracking
Block cracking
Crocodile cracking
Patching
Shoving

Source: Queensland Department of Transport and Main Roads (2006).

PAVEMENT DEFECT MAPPING SHEET

Road Name: South Dodd   Inspector Initials: KE

Suburb: H. BAY

Description:

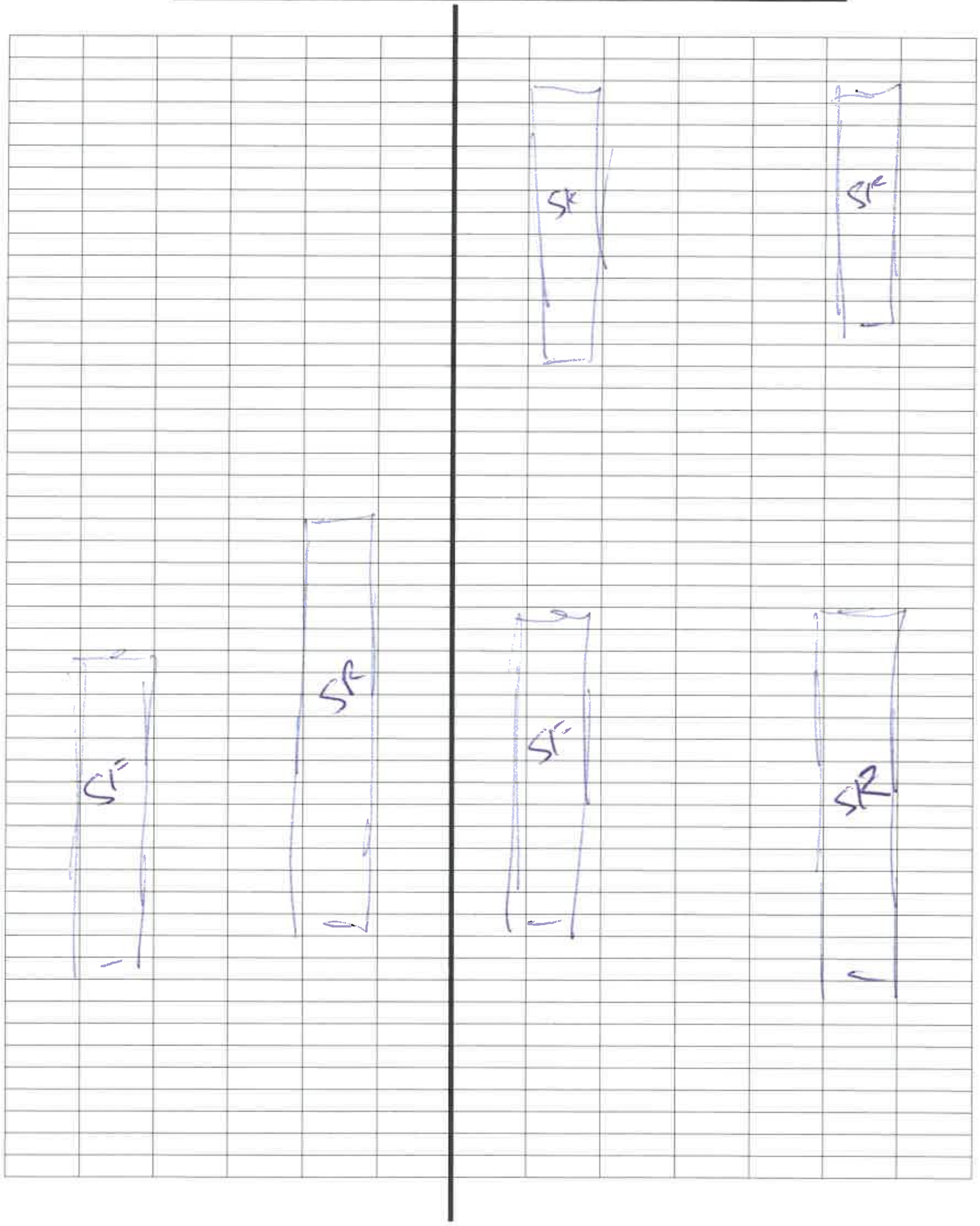
CH 800

CH 700

CH 600

CH 500

CH 400



SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)

Crescent (shear) cracking

Block cracking

Crocodile cracking

Patching

Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record

Site Name:	OLEANDER AVE HERVEY BAY	**Year Constructed**	2016
Weather Conditions:	FINE	**Time:**	7am
Site Record	Traffic Conditions (Vehicle Types, volumes etc.): * HIGH TRAFFIC VOLUME – MOSTLY CARS * LOW HEAVY VEHICLES.		
Identified Defects	* NO IDIENTIFIED DEFECTS * VERY SMALL RUT DEPTHS.		
Overall Pavement Condition (1=best)	1..✓...........3..........5..........7..........10		
Signature	Inspector	Date: 28/08/20	

Site Visit Record

Site Name:	Amity St Maryborough	**Year Constructed**	2015
Weather Conditions:	Fine	**Time:**	11am

Site Record

Traffic Conditions (Vehicle Types, volumes etc.):

Very Low Traffic at time of insp.

Identified Defects

Very minor flushing

1x Patch — potential pothole repair

Overall Pavement Condition (1=best)

1…✓…………………3……………………………………5……………………………………7………………………………10

Signature

[signature]

Inspector

28/7/20.

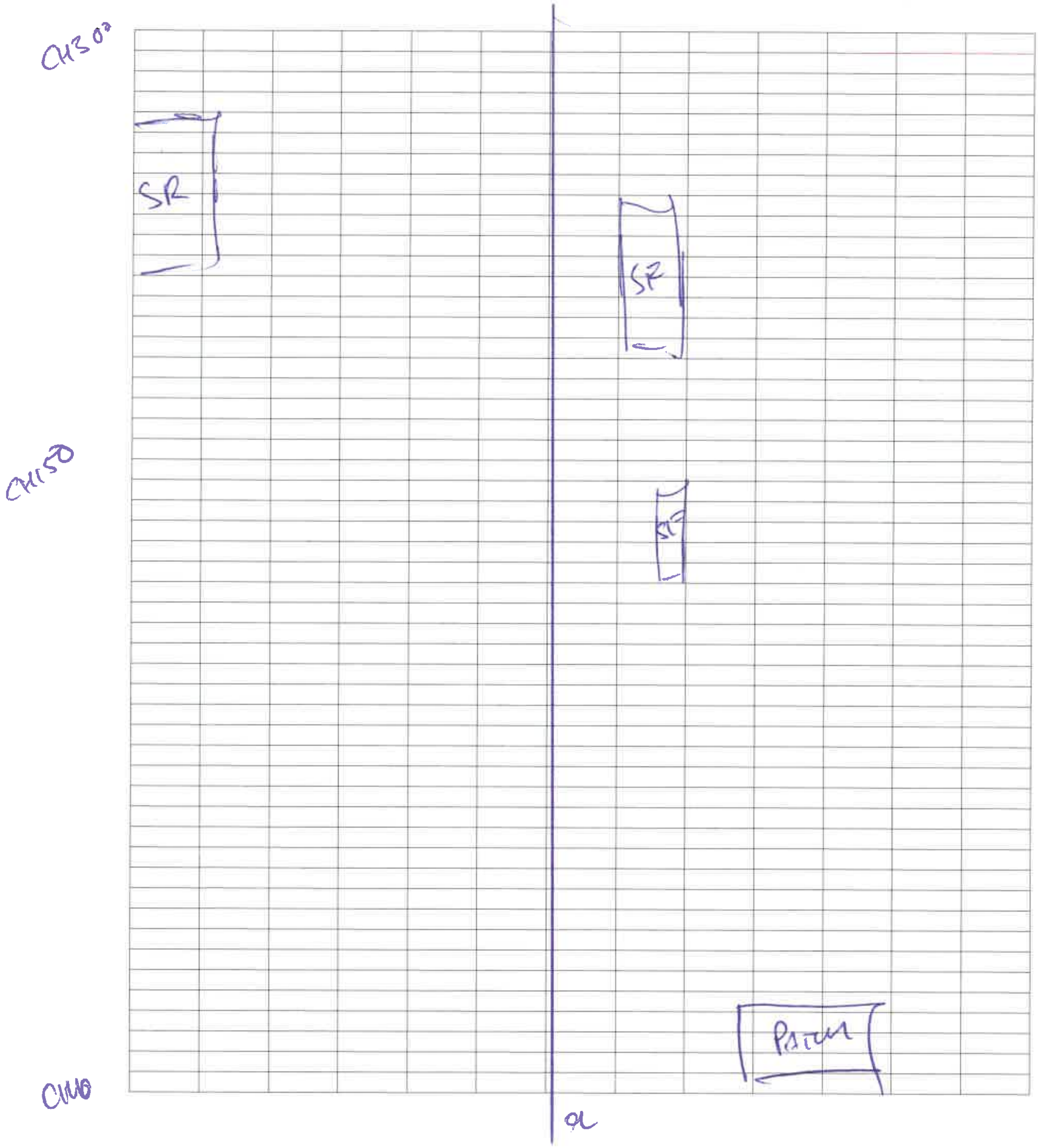
Date

PAVEMENT DEFECT MAPPING SHEET

Road Name: Avery St Inspector Initials: Ke

Suburb:

Description:



SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)
Crescent (shear) cracking

Block cracking
Crocodile cracking

Patching
Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record

Site Name:	YERRA ROAD	**Year Constructed**	2015
Weather Conditions:	FINE	**Time:**	1pm

Site Record

Traffic Conditions (Vehicle Types, volumes etc.):

* HIGH HEAVY VEHICLES
* CANE TRUCKS
* LOW TRAFFIC

Identified Defects

* RUTTING
* DEFORMATION
* FLUSHING

Overall Pavement Condition (1=best)

1..................................3..5..................................✓.........7......................................10

Signature

Inspector

10/8/20

Date

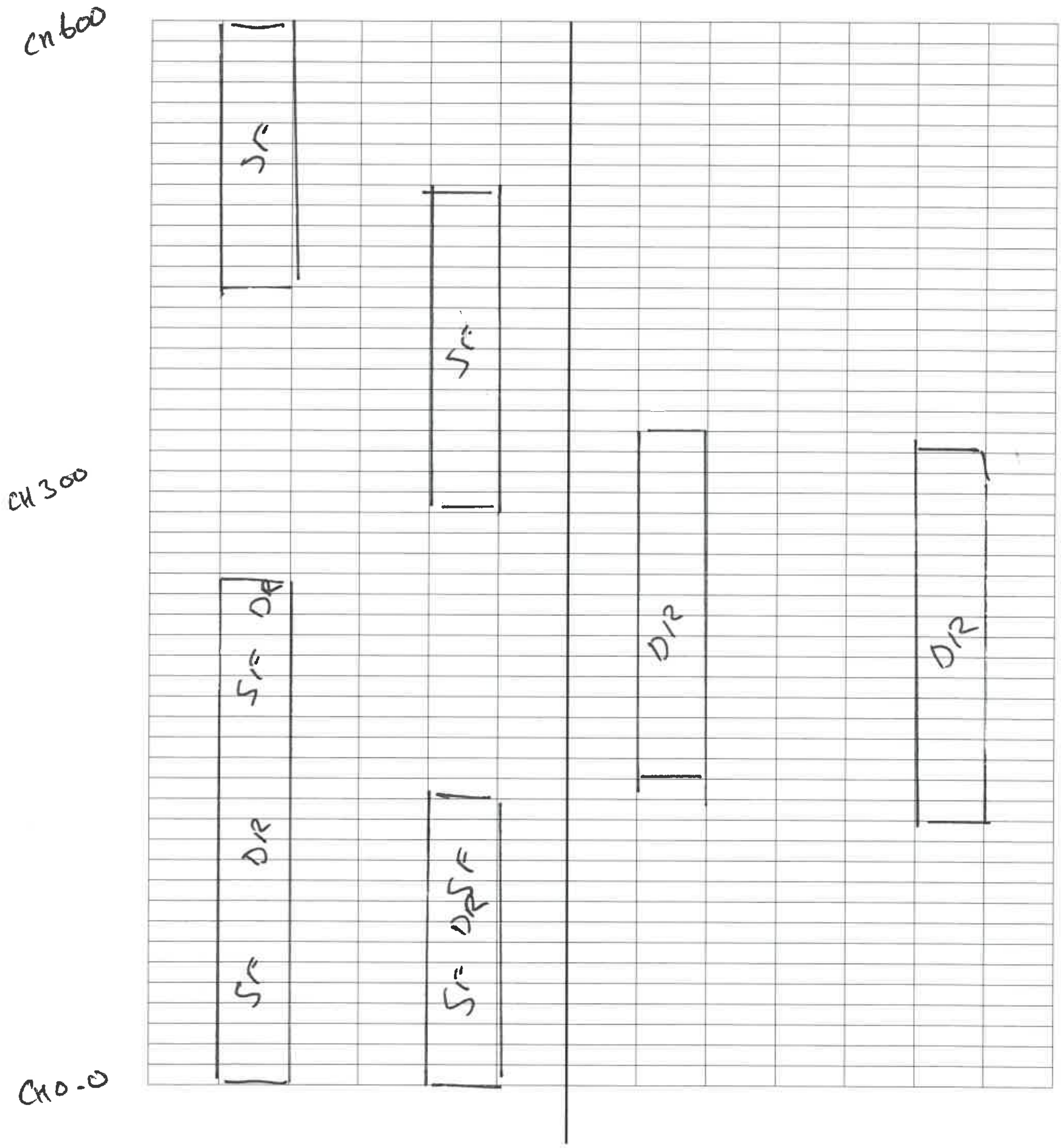
PAVEMENT DEFECT MAPPING SHEET

Road Name: YERRA ROAD

Inspector Initials: KE

Suburb: MARYBOROUGH

Description:



SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)

Crescent (shear) cracking

Block cracking

Crocodile cracking

Patching

Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record			
Site Name:	BEAVER ROCK ROAD	**Year Constructed**	2016
Weather Conditions:		**Time:**	2pm
Site Record	Traffic Conditions (Vehicle Types, volumes etc.): * CANE TRUCKS * LOW TRAFFIC		
Identified Defects	* MINOR FLUSHING. * RUTTING * ISOLATED DEFORMATION		
Overall Pavement Condition (1=best)	1...............3...............5.......✓.......7...............10		
Signature	Inspector	10/08/20 Date	

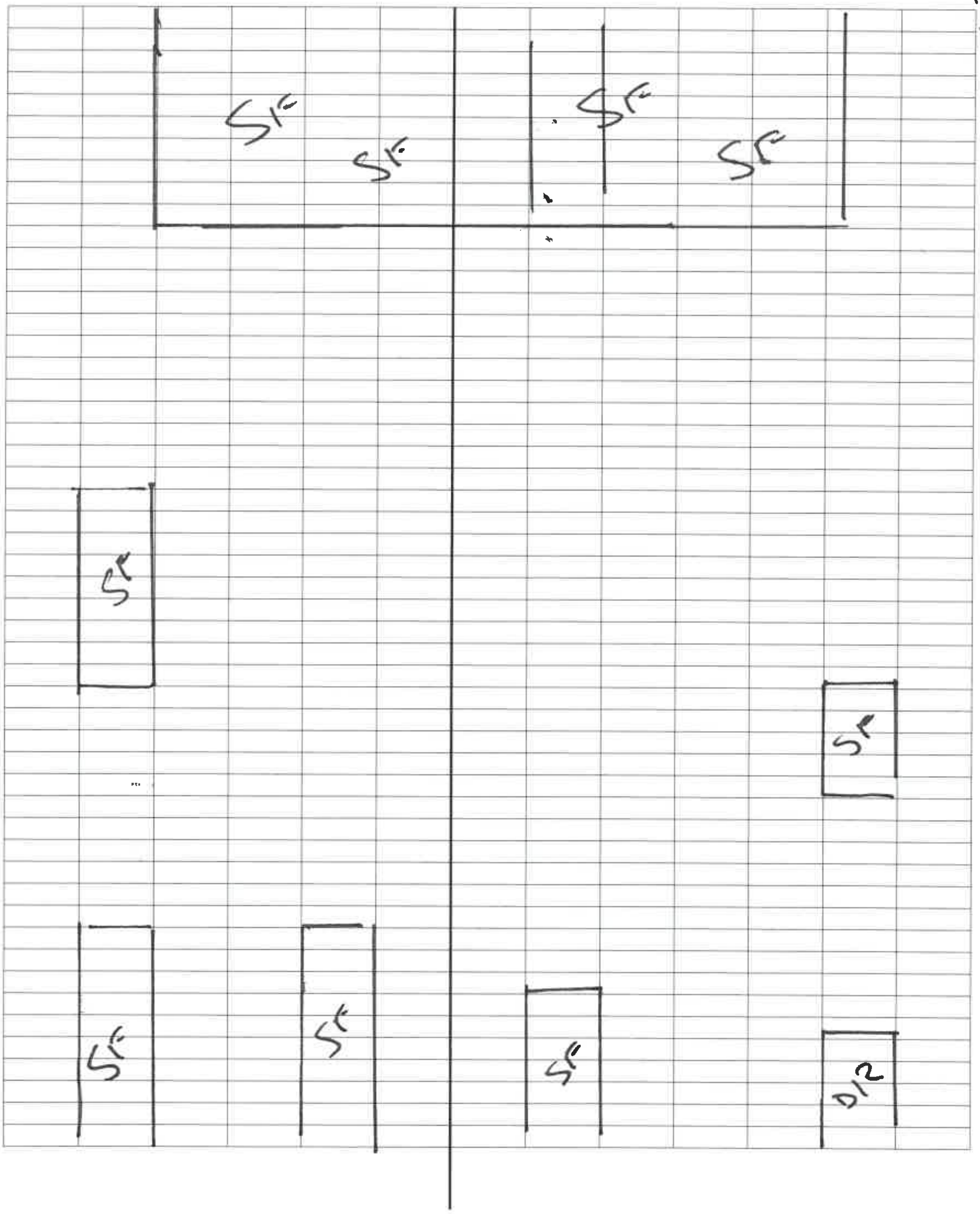
PAVEMENT DEFECT MAPPING SHEET

Road Name: BEAVER ROCK RD Inspector Initials: Ke

Suburb: MARYBOROUGH

Description:

CH1000 INTERSECTION



CH0.

SR - Raveling
SS - Stripping
SF - Flushing
DS - Shoving
DR - Rutting

DC - Corrugation
PA - Patch
HO - Pothole

Crack (P- pumping)
Crescent (shear) cracking
Block cracking
Crocodile cracking
Patching
Shoving

Source: Queensland Department of Transport and Main Roads (2006).

Site Visit Record			
Site Name:	WARD ST MARYBOROUGH	**Year Constructed**	
Weather Conditions:	FINE	**Time:**	2.50 pm
Site Record	Traffic Conditions (Vehicle Types, volumes etc.): • NO PASSING TRAFFIC AT TIME OF INSPECTION • LIKELY ONLY RESIDENTIAL TRAFFIC		
Identified Defects	* NO DEFECTS NOTED • PAVEMENT APPEARS TO BE IN VERY GOOD CONDITION.		
Overall Pavement Condition (1=best)	1.....✓.....3.....5.....7.....10		
Signature	Inspector		19/08/20 Date

Appendix C

Site Traffic Counts

Fraser Coast Regional Council

PO Box 1943
Hervey Bay

Main St, Kawungan
210m Nth Urraween Rd
03-Sep-19 18 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	94.4	224,872	-----	
	2	3	3	1.3	3,199	-----	
Medium 5.5m to 14.5m	3	2	2	3.5	8,408	16,816	
	4	3	2	0.2	472	944	
	5	4	2	0.1	301	602	
Long 11.5m to 19.0m	6	3	3	0.1	203	609	
	7	4	2	0.1	158	316	
	8	5	3	0.0	79	237	
	9	6	3	0.1	352	1,056	
Medium Combo 17.5m to 36.5m	10	7	4	0.1	143	572	
	11	9	5	0.0	36	180	
Long Combo over 33.0m	12	9	7	0.0	23	161	
			HV	4.3	238,246	21,493	
			NHVAG	2.10			

Unclassifiable Class					
Unclassifiable axle event	13	0.035	83	Exclude	

AADT=	13,241	Design Life=		ESA/HVAG=	0.7
Lane Factor=	1	Ntd=			
Direction factor=	0.5	DESA=			
Assume Growth=	2%				

Volumes				
	All Days	Weekdays	Weekend	AADT
Both Direction	238,329	197,589	40,740	13,241
North	118,612	98,137	20,475	6,590
South	119,717	99,452	20,265	6,651

Class and Volume Percentage by Direction				
Class	North	South	% North	% South
1 - SV	113,447	111,425	95.7	93.1
2 - SVT	1,641	1,558	1.4	1.3
3 - TB2	2,670	5,738	2.3	4.8
4 - TB3	228	244	0.2	0.2
5 - T4	151	150	0.1	0.1
6 - ART3	63	140	0.1	0.1
7 - ART4	58	100	0.0	0.1
8 - ART5	45	34	0.0	0.0
9 - ART6	183	169	0.2	0.1
10 - BD	62	81	0.1	0.1
11 - DRT	15	21	0.0	0.0
12 - TRT	10	13	0.0	0.0

Peak Volumes, Time and Direction				
	All Days	Weekdays	Weekend	Virtual Daily
AM Peak - Volume	19999 (1100)	16787 (0800)	4393 (1100)	1111 (1100)
AM Peak - Percent	8.4%	8.5%	10.8%	8.4%
North	9779 (1100)	7691 (1100)	2088 (1100)	543 (1100)
South	12556 (0800)	11264 (0800)	2392 (1000)	698 (0800)
PM Peak - Volume	20824 (1500)	17642 (1500)	4016 (1200)	1157 (1500)
PM Peak - Percent	8.7%	8.9%	9.9%	8.7%
North	10889 (1500)	9337 (1700)	2120 (1200)	605 (1500)
South	9935 (1500)	8532 (1500)	1896 (1200)	552 (1500)

Speed				
	All Days	Weekdays	Weekend	
Mean speed	64.2	64	65	km/h
Max Speed	154.5	150.4	154.5	km/h
Median speed	69.8	69.7	70.5	km/h
85% speed	69.8	69.7	70.5	km/h
Peak speed	154.5	150.4	154.5	km/h
Speed at start of pace	56.4	56.3	57.2	15/Km/h
Percent in pace	82.3	82.3	82.6	
Mean Exceeding	66.4	66.3	66.8	km/h
Number speeding	184,055	151,020	33,035	
Percent speeding	77.2	76.4	81.1	%

Posted speed limit = 60 km/h

Fraser Coast Regional Council

PO Box 1943

Hervey Bay

Chapel Rd, Nikenbah
500m Wst Madsen Rd
18-Jan-17 13 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	71.7	18,867	-----	
	2	3	3	10.9	2,866	-----	
Medium 5.5m to 14.5m	3	2	2	10.8	2,849	5,698	
	4	3	2	2.2	589	1,178	
	5	4	2	0.8	211	422	
Long 11.5m to 19.0m	6	3	3	1.1	297	891	
	7	4	2	0.5	131	262	
	8	5	3	0.3	67	201	
	9	6	3	1.2	320	960	
Medium Combo 17.5m to 36.5m	10	7	4	0.5	119	476	
	11	9	5	0.0	8	40	
Long Combo over 33.0m	12	9	7	0.0	1	7	
			HV	17.4	26,325	10,135	
			NHVAG	2.21			

Unclassifiable Class					
Unclassifiable axle event	13	0.008	2	Exclude	

AADT= 2,025
Lane Factor= 1
Direction factor= 0.5
Assume Growth= 2%

Design Life=
Ntd=
DESA=

ESA/HVGA= 0.7

Volumes				
	All Days	Weekdays	Weekend	AADT
Both Direction	26,327	19,019	7,308	2,025
West	13,243	9,535	3,708	1,019
East	13,084	9,484	3,600	1,006

Class and Volume Percentage by Direction				
Class	**West**	**East**	**% West**	**% East**
1 - SV	9,628	9,239	72.7	70.6
2 - SVT	1,457	1,409	11.0	10.8
3 - TB2	1,331	1,518	10.1	11.6
4 - TB3	276	313	2.1	2.4
5 - T4	108	103	0.8	0.8
6 - ART3	138	159	1.0	1.2
7 - ART4	63	68	0.5	0.5
8 - ART5	22	45	0.2	0.3
9 - ART6	161	159	1.2	1.2
10 - BD	52	67	0.4	0.5
11 - DRT	6	2	0.0	0.0
12 - TRT	1	0	0.0	0.0

Peak Volumes, Time and Direction				
	All Days	**Weekdays**	**Weekend**	**Virtual Daily**
AM Peak - Volume	2774 (0800)	2106 (0800)	937 (0900)	213 (0800)
AM Peak - Percent	10.50%	11.10%	12.80%	10.50%
West	1534 (0800)	1145 (0800)	549 (0900)	118 (0800)
East	1253 (1000)	961 (0800)	499 (1100)	96 (1000)
PM Peak - Volume	2179 (1500)	1734 (1500)	682 (1200)	168 (1500)
PM Peak - Percent	8.30%	9.10%	9.30%	8.30%
West	1087 (1500)	875 (1500)	289 (1200)	84 (1500)
East	1198 (1200)	859 (1500)	393 (1200)	92 (1200)

Speed				
	All Days	**Weekdays**	**Weekend**	
Mean speed	66.9	66.6	67.7	km/h
Max Speed	126.4	126.3	126.4	km/h
Median speed	76.9	76.9	77.1	km/h
85% speed	76.9	76.9	77.1	km/h
Peak speed	126.4	126.3	126.4	km/h
Speed at start of pace	58.1	58.1	58.4	15/Km/h
Percent in pace	59.9	59.2	61.8	
Mean Exceeding	70.6	70.6	70.7	km/h
Number speeding	20,478	14,580	5,898	
Percent speeding	77.8	76.7	80.7	%

Posted speed limit = 60 km/h

Fraser Coast Regional Council

PO Box 1943

Hervey Bay

Doolong Sth Rd, Wondunna
100m Sth Doolong Rd
06-Aug-19 27 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	91.6	99,355	-----	
	2	3	3	3.5	3,787	-----	
Medium 5.5m to 14.5m	3	2	2	4.0	4,338	8,676	
	4	3	2	0.4	387	774	
	5	4	2	0.1	105	210	
Long 11.5m to 19.0m	6	3	3	0.2	200	600	
	7	4	2	0.1	150	300	
	8	5	3	0.0	18	54	
	9	6	3	0.1	90	270	
Medium Combo 17.5m to 36.5m	10	7	4	0.0	7	28	
	11	9	5	0.0	10	50	
Long Combo over 33.0m	12	9	7	0.0	4	28	
			HV	4.9	108,451	10,990	
			NHVAG	2.07			

Unclassifiable Class					
Unclassifiable axle event	13	0.033	36	Exclude	

AADT= 4,018
Lane Factor= 1
Direction factor= 0.5
Assume Growth= 2%

Design Life=
Ntd=
DESA=

ESA/HVAG= 0.7

Volumes				
	All Days	Weekdays	Weekend	AADT
Both Direction	108,487	82,873	25,614	4,018
North	55,900	42,675	13,225	2,070
South	52,587	40,198	12,389	1,948

Class and Volume Percentage by Direction				
Class	North	South	% North	% South
1 - SV	50,703	48,652	90.7	92.5
2 - SVT	1,847	1,940	3.3	3.7
3 - TB2	2,780	1,558	5.0	3.0
4 - TB3	193	194	0.3	0.4
5 - T4	47	58	0.1	0.1
6 - ART3	157	43	0.3	0.1
7 - ART4	109	41	0.2	0.1
8 - ART5	11	7	0.0	0.0
9 - ART6	42	48	0.1	0.1
10 - BD	2	5	0.0	0.0
11 - DRT	2	8	0.0	0.0
12 - TRT	0	4	0.0	0.0

Peak Volumes, Time and Direction				
	All Days	Weekdays	Weekend	Virtual Daily
AM Peak - Volume	14985 (0800)	13170 (0800)	2380 (1100)	555 (0800)
AM Peak - Percent	13.80%	15.90%	9.30%	13.80%
North	8243 (0800)	7436 (0800)	1352 (1100)	305 (0800)
South	6742 (0800)	5734 (0800)	1166 (0900)	250 (0800)
PM Peak - Volume	12969 (1500)	11038 (1500)	2138 (1200)	480 (1500)
PM Peak - Percent	12.00%	13.30%	8.30%	12.00%
North	6579 (1500)	5557 (1500)	1111 (1200)	244 (1500)
South	6390 (1500)	5481 (1500)	1027 (1200)	237 (1500)

Speed				
	All Days	Weekdays	Weekend	
Mean speed	57.6	57.3	58.8	km/h
Max Speed	136.9	110	136.9	km/h
Median speed	63.1	62.6	64.4	km/h
85% speed	63.1	62.6	64.4	km/h
Peak speed	136.9	110	136.9	km/h
Speed at start of pace	50.2	50	51.2	15/Km/h
Percent in pace	83.6	83.9	83.3	
Mean Exceeding	64.1	64	64.4	km/h
Number speeding	33,523	23,469	10,054	
Percent speeding	30.9	28.3	39.3	%

Posted speed limit = 60 km/h

Fraser Coast Regional Council

PO Box 1943

Hervey Bay

Oleander Av, Kawungan
100m Wst Denmans Camp Rd
20-Jun-18 8 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	95.7	34,858	-----	
	2	3	3	1.3	485	-----	
Medium 5.5m to 14.5m	3	2	2	2.5	897	1,794	
	4	3	2	0.1	52	104	
	5	4	2	0.1	30	60	
Long 11.5m to 19.0m	6	3	3	0.1	31	93	
	7	4	2	0.1	25	50	
	8	5	3	0.0	7	21	
	9	6	3	0.1	22	66	
Medium Combo 17.5m to 36.5m	10	7	4	0.0	0	0	
	11	9	5	0.0	0	0	
Long Combo over 33.0m	12	9	7	0.0	0	0	
			HV	2.9	36407	2188	
			NHVAG	2.07			

Unclassifiable Class					
Unclassifiable axle event	13	0.1	23	Exclude	

AADT= 4,554
Lane Factor= 1
Direction factor= 0.5
Assume Growth= 2%

Design Life=
Ntd=
DESA=

ESA/HVAG= 0.7

Volumes

	All Days	Weekdays	Weekend	AADT
Both Direction	36,430	29,048	7,382	4,554
East	17,616	13,933	3,683	2,202
West	18,814	15,115	3,699	2,352

Class and Volume Percentage by Direction

Class	East	West	% East	% West
1 - SV	16,753	18,105	95.1	96.2
2 - SVT	232	253	1.3	1.3
3 - TB2	550	347	3.1	1.8
4 - TB3	19	33	0.1	0.2
5 - T4	7	23	0.0	0.1
6 - ART3	22	9	0.1	0.0
7 - ART4	14	11	0.1	0.1
8 - ART5	1	6	0.0	0.0
9 - ART6	10	12	0.1	0.1
10 - BD	0	0	0.0	0.0
11 - DRT	0	0	0.0	0.0
12 - TRT	0	0	0.0	0.0

Peak Volumes, Time and Direction

	All Days	Weekdays	Weekend	Virtual Daily
AM Peak - Volume	3331 (0800)	2888 (0800)	749 (1100)	416 (0800)
AM Peak - Percent	9.10%	9.90%	10.10%	9.10%
East	1426 (1100)	1059 (1100)	367 (1100)	178 (1100)
West	2125 (0800)	1875 (0800)	405 (1000)	266 (0800)
PM Peak - Volume	3499 (1500)	2950 (1500)	774 (1200)	437 (1500)
PM Peak - Percent	9.60%	10.20%	10.50%	9.60%
East	1666 (1500)	1377 (1600)	398 (1200)	208 (1500)
West	1833 (1500)	1585 (1500)	376 (1200)	229 (1500)

Speed

	All Days	Weekdays	Weekend	
Mean speed	50.7	50.6	51.2	km/h
Max Speed	99.7	97.5	99.7	km/h
Median speed	56.3	56.2	56.8	km/h
85% speed	56.3	56.2	56.8	km/h
Peak speed	99.7	97.5	99.7	km/h
Speed at start of pace	43.6	43.6	43.6	15/Km/h
Percent in pace	83.0	83.2	81.9	
Mean Exceeding	62.8	62.7	63.1	km/h
Number speeding	1,588	1,166	422	
Percent speeding	4.4	4.0	5.7	%

Posted speed limit = 60 km/h

Fraser Coast Regional Council

PO Box 1943

Hervey Bay

Yerra Rd Yerra
200m Nth Pilerwa Rd
15-Jul-20 12 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	71.0	1,095	-----	
	2	3	3	3.0	47	-----	
Medium 5.5m to 14.5m	3	2	2	16.7	257	514	
	4	3	2	2.1	32	64	
	5	4	2	0.8	13	26	
Long 11.5m to 19.0m	6	3	3	0.7	11	33	
	7	4	2	1.1	17	34	
	8	5	3	0.5	8	24	
	9	6	3	2.1	33	99	
Medium Combo 17.5m to 36.5m	10	7	4	1.8	28	112	
	11	9	5	0.1	2	10	
Long Combo over 33.0m	12	9	7	0.0	0	0	
			HV	26.0	1,543	916	
			NHVAG	2.28			

Unclassifiable Class					
Unclassifiable axle event	13	0	0	Exclude	

AADT= 129
Lane Factor= 1
Direction factor= 0.5
Assume Growth= 2%

Design Life=
Ntd=
DESA=

ESA/HVAG= 0.7

Volumes

	All Days	Weekdays	Weekend	AADT
Both Direction	1,543	1,210	333	129
North	772	605	167	64
South	771	605	166	64

Class and Volume Percentage by Direction

Class	North	South	% North	% South
1 - SV	480	615	62.2	79.8
2 - SVT	24	23	3.1	3.0
3 - TB2	186	71	24.1	9.2
4 - TB3	17	15	2.2	1.9
5 - T4	6	7	0.8	0.9
6 - ART3	8	3	1.0	0.4
7 - ART4	13	4	1.7	0.5
8 - ART5	4	4	0.5	0.5
9 - ART6	19	14	2.5	1.8
10 - BD	14	14	1.8	1.8
11 - DRT	1	1	0.1	0.1
12 - TRT	0	0	0.0	0.0

Peak Volumes, Time and Direction

	All Days	Weekdays	Weekend	Virtual Daily
AM Peak - Volume	148 (0800)	120 (0800)	28 (0800)	12 (0800)
AM Peak - Percent	9.60%	9.90%	8.40%	9.60%
North	83 (0800)	68 (0800)	15 (0800)	7 (0800)
South	65 (0800)	58 (0600)	16 (1100)	5 (0800)
PM Peak - Volume	157 (1600)	124 (1600)	33 (1600)	13 (1600)
PM Peak - Percent	10.20%	10.20%	9.90%	10.20%
North	79 (1600)	62 (1600)	19 (1200)	7 (1600)
South	78 (1600)	62 (1600)	18 (1300)	7 (1600)

Speed

	All Days	Weekdays	Weekend	
Mean speed	86.2	86.4	85.4	km/h
Max Speed	143	143	141.4	km/h
Median speed	103.1	103.4	103	km/h
85% speed	103.1	103.4	103	km/h
Peak speed	143	143	141.4	km/h
Speed at start of pace	80.3	80.3	80.8	15/Km/h
Percent in pace	36.2	37.0	33.9	
Mean Exceeding	109	108.6	110.4	km/h
Number speeding	317	249	68	
Percent speeding	20.5	20.6	20.4	%

Posted speed limit = 100 km/h

Fraser Coast Regional Council

PO Box 1943

Hervey Bay

Beaver Rock Rd, Beaver Rock
100m Est Walkers Pt Rd
07-Apr-20 10 days

Length Type	Class	Axles	Groups	% in count	No in count	HVAG	
Short up to 5.5m	1	2	2	61.2	1,245	-----	
	2	3	3	16.0	325	-----	
Medium 5.5m to 14.5m	3	2	2	15.1	307	614	
	4	3	2	0.3	6	12	
	5	4	2	0.3	6	12	
Long 11.5m to 19.0m	6	3	3	5.9	121	363	
	7	4	2	1.0	20	40	
	8	5	3	0.0	0	0	
	9	6	3	0.0	0	0	
Medium Combo 17.5m to 36.5m	10	7	4	0.0	0	0	
	11	9	5	0.0	0	0	
Long Combo over 33.0m	12	9	7	0.0	0	0	
			HV	22.6	2,030	1,041	
			NHVAG	2.27			

Unclassifiable Class					
Unclassifiable axle event	13	0.295	6	Exclude	

AADT= 204

Lane Factor= 1

Direction factor= 0.5

Assume Growth= 2%

Design Life=

Ntd=

DESA=

ESA/HVAG= 0.7

Volumes

	All Days	Weekdays	Weekend	AADT
Both Direction	2,036	1,609	427	204
East	1,038	817	221	104
West	998	792	206	100

Class and Volume Percentage by Direction

Class	East	West	% East	% West
1 - SV	770	475	74.2	47.6
2 - SVT	225	100	21.7	10.0
3 - TB2	20	287	1.9	28.8
4 - TB3	3	3	0.3	0.3
5 - T4	5	1	0.5	0.1
6 - ART3	5	116	0.5	11.6
7 - ART4	4	16	0.4	1.6
8 - ART5	0	0	0.0	0.0
9 - ART6	0	0	0.0	0.0
10 - BD	0	0	0.0	0.0
11 - DRT	0	0	0.0	0.0
12 - TRT	0	0	0.0	0.0

Peak Volumes, Time and Direction

	All Days	Weekdays	Weekend	Virtual Daily
AM Peak - Volume	179 (0900)	139 (1100)	45 (0900)	18 (0900)
AM Peak - Percent	8.80%	8.60%	10.50%	8.80%
East	106 (1100)	80 (1100)	26 (0900)	11 (1100)
West	92 (0900)	73 (0900)	19 (0900)	9 (0900)
PM Peak - Volume	176 (1400)	140 (1400)	36 (1300)	18 (1400)
PM Peak - Percent	8.60%	8.70%	8.40%	8.60%
East	81 (1300)	67 (1300)	18 (1400)	8 (1300)
West	97 (1400)	79 (1400)	22 (1300)	10 (1400)

Speed

	All Days	Weekdays	Weekend	
Mean speed	61	61.5	59.2	km/h
Max Speed	116.5	116.5	98.3	km/h
Median speed	75.5	75.6	75	km/h
85% speed	75.5	75.6	75	km/h
Peak speed	116.5	116.5	98.3	km/h
Speed at start of pace	52.6	52.6	52.6	15/Km/h
Percent in pace	46.1	45.9	46.8	
Mean Exceeding	85.7	85.6	86.2	km/h
Number speeding	170	143	27	
Percent speeding	8.4	8.9	6.3	%

Posted speed limit = 80 km/h

Appendix D

Design Check Calculations

Main St	
AADT	13241
Lane Factor	1
Distributino Factor	0.5
CGF	41.6
HV %	4%
Nhvag	2.1
Opening HV/Day	284.6815
NDT	9,077,468.18
DESA	6,354,227.73
=	6.35E+06

Chapel Rd	
AADT	2025
Lane Factor	1
Distributino Factor	0.5
CGF	1166.140147
HV %	17%
Nhvag	2.21
Opening HV/Day	176.175
NDT	165,721,999.82
DESA	116,005,399.87
=	1.16E+08

Oleander Ave	
AADT	4554
Lane Factor	1
Distributino Factor	0.5
CGF	54.65
HV %	3%
Nhvag	2.07
Opening HV/Day	66.033
NDT	2,726,555.89
DESA	1,908,589.12
=	1.91E+06

Doolong	
AADT	4018
Lane Factor	1
Distributino Factor	0.5
CGF	790.9479913
HV %	5%
Nhvag	2.07
Opening HV/Day	98.441
NDT	58,828,415.91
DESA	41,179,891.14
=	4.12E+07

Yerra Road	
AADT	129
Lane Factor	1
Distributino Factor	0.5
CGF	95
HV %	26%
Nhvag	2.28
Opening HV/Day	16.77
NDT	1,325,819.43
DESA	928,073.60
=	9.28E+05

Beaver Rock	
AADT	204
Lane Factor	1
Distributino Factor	0.5
CGF	40
HV %	23%
Nhvag	2.27
Opening HV/Day	23.052
NDT	763,989.38
DESA	534,792.57
=	5.35E+05

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Chapel Road Design Check

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 4.48E+06

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 5 Title: Chapel Road

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Cement3500	Iso.	3.50E+03	0.20			
2	rough	Sub_CBR4	Aniso.	4.00E+01	0.45	2.76E+01	2.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
1	bottom	Cement3500	ETH	0.000350	12.000	
2	top	Sub_CBR4	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
1	1.00	Cement Stabilised
2	1.00	Subgrade (Austroads 2017)

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
1	300.00	Cement3500		
			SADT(80):	1.198E-04
			SAST(53):	8.869E-05
2	0.00	Sub_CBR4		
			SADT(80):	3.175E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	300.00	Cement3500	Total:	6.854E+00
			SAST:	2.220E+00
			SADT:	1.791E+00
			TAST:	3.283E-02
			TADT:	2.579E+00
			TRDT:	2.309E-01
			QADT:	0.000E+00
2	0.00	Sub_CBR4	Total:	1.901E-04

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Chapel Road Design Check

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 1.66E+08

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 5 Title: Chapel Road

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Cement3500	Iso.	3.50E+03	0.20			
2	rough	Sub_CBR4	Aniso.	4.00E+01	0.45	2.76E+01	2.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
1	bottom	Cement3500	ETH	0.000350	12.000	
2	top	Sub_CBR4	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
1	1.00	Cement Stabilised
2	1.00	Subgrade (Austroads 2017)

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
1	405.00	Cement3500		
			SADT(80):	7.622E-05
			SAST(53):	5.333E-05
2	0.00	Sub_CBR4		
			SADT(80):	2.041E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	405.00	Cement3500	Total:	9.351E-01
			SAST:	1.840E-01
			SADT:	2.913E-01
			TAST:	2.721E-03
			TADT:	4.195E-01
			TRDT:	3.756E-02
			QADT:	0.000E+00
2	0.00	Sub_CBR4	Total:	3.195E-04

Appendix E

LCCA Traffic Calculations

Low Order Road	
AADT	200
Lane Factor	1
Distributino Factor	0.5
CGF	41.3
HV %	3%
Nhvag	2.1
Opening HV/Day	2.9
NDT	91,803.71
DESA	64,262.59
=	6.43E+04

High Order Road	
AADT	5000
Lane Factor	1
Distributino Factor	0.5
CGF	41.3
HV%	10%
Nhvag	2.1
Opening HV/Day	250
NDT	7,914,112.50
DESA	5,539,878.75
=	5.54E+06

Appendix F

LCCA CIRCLY Models

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Unbound Granular

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 9.18E+04

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: Aust2017-1 Title: Austroads 2017 - Example 1 - Unbound Granular Pavement

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Gran_150	Aniso.	1.50E+02	0.35	1.11E+02	7.50E+01	0.35
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 97.5%

Layer No.	Reliability Factor	Material Type
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering
Layer no. 2: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
3	0.00	Sub_CBR2		
			SADT(80):	1.849E-03

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	250.00	Gran_350		n/a
2	260.00	Gran_150		n/a
3	0.00	Sub_CBR2	Total:	8.844E-01

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Unbound Granular

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 7.91E+06

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: Aust2017-1 Title: Austroads 2017 - Example 1 - Unbound Granular Pavement

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Gran_150	Aniso.	1.50E+02	0.35	1.11E+02	7.50E+01	0.35
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 97.5%

Layer No.	Reliability Factor	Material Type
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering
Layer no. 2: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
3	0.00	Sub_CBR2		
			SADT(80):	9.923E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	250.00	Gran_350		n/a
2	475.00	Gran_150		n/a
3	0.00	Sub_CBR2	Total:	9.768E-01

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Modified Granular

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 9.81E+04

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 2 Title: Modified Granular Low Order Road

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Cem500A	Aniso.	5.00E+02	0.35	3.70E+02	2.50E+02	0.35
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
3	0.00	Sub_CBR2		
			SADT(80):	1.860E-03

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	150.00	Gran_350		n/a
2	160.00	Cem500A		n/a
3	0.00	Sub_CBR2	Total:	9.835E-01

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Modified Granular

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 7.91E+06

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 2 Title: Modified Granular High Order Road

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Cem500A	Aniso.	5.00E+02	0.35	3.70E+02	2.50E+02	0.35
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
3	0.00	Sub_CBR2		
			SADT(80):	9.810E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	230.00	Gran_350		n/a
2	250.00	Cem500A		n/a
3	0.00	Sub_CBR2	Total:	9.017E-01

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Leanmix

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 9.18E+04

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 3 Title: leanmix High Order

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Cemen10000	Iso.	1.00E+04	0.20			
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
2	bottom	Cemen10000	ETH	0.000260	12.000	
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
2	1.00	Cement Stabilised
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
2	175.00	Cemen10000		
			SADT(80):	1.058E-04
			SAST(53):	7.567E-05
3	0.00	Sub_CBR2		
			SADT(80):	4.400E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	155.00	Gran_350		n/a
2	175.00	Cemen10000	Total:	9.950E-01
			SAST:	2.397E-01
			SADT:	2.926E-01
			TAST:	3.545E-03
			TADT:	4.214E-01
			TRDT:	3.774E-02
			QADT:	0.000E+00
3	0.00	Sub_CBR2	Total:	3.821E-05

CIRCLY - Version 7.0 (18 March 2019)

Job Title: Leanmix

Design Method: Austroads 2017

NDT (cumulative heavy vehicle axle groups over design period): 7.91E+06

Traffic Load Distribution:

ID: _Example
Name: Example traffic load distribution (from Austroads Guide, Appendix G)
ESA/HVAG: 0.700

Details of Load Groups:

Load No.	Load ID	Load Category	Load Type	Radius	Pressure/ Ref. stress	Exponent
1	ESA750-Full	ESA750-Full	Vertical Force	92.1	0.75	0.00
2	SAST53	SAST53	Vertical Force	102.4	0.80	0.00

Load Locations:

Location No.	Load ID	Gear No.	X	Y	Scaling Factor	Theta
1	ESA750-Full	1	-165.0	0.0	1.00E+00	0.00
2	ESA750-Full	1	165.0	0.0	1.00E+00	0.00
3	ESA750-Full	1	1635.0	0.0	1.00E+00	0.00
4	ESA750-Full	1	1965.0	0.0	1.00E+00	0.00
1	SAST53	1	0.0	0.0	1.00E+00	0.00
2	SAST53	1	2130.0	0.0	1.00E+00	0.00

Details of Layered System:

ID: 3 Title: leanmix High Order

Layer No.	Lower i/face	Material ID	Isotropy	Modulus (or Ev)	P.Ratio (or vvh)	F	Eh	vh
1	rough	Gran_350	Aniso.	3.50E+02	0.35	2.59E+02	1.75E+02	0.35
2	rough	Cemen10000	Iso.	1.00E+04	0.20			
3	rough	Sub_CBR2	Aniso.	2.00E+01	0.45	1.38E+01	1.00E+01	0.45

Performance Relationships:

Layer No.	Location	Material ID	Component	Perform. Constant	Perform. Exponent	Shift Factor
2	bottom	Cemen10000	ETH	0.000260	12.000	
3	top	Sub_CBR2	EZZ	0.009150	7.000	

Reliability Factors:
Project Reliability: Austroads 95%

Layer No.	Reliability Factor	Material Type
2	1.00	Cement Stabilised
3	1.00	Subgrade (Austroads 2017)

Details of Layers to be sublayered:
Layer no. 1: Austroads (2004) sublayering

Strains:

Layer No.	Thickness	Material ID	Axle	Unitless Strain
2	220.00	Cemen10000		
			SADT(80):	7.356E-05
			SAST(53):	5.023E-05
3	0.00	Sub_CBR2		
			SADT(80):	3.083E-04

Results:

Layer No.	Thickness	Material ID	Axle Group	CDF
1	200.00	Gran_350		n/a
2	220.00	Cemen10000	Total:	9.788E-01
			SAST:	1.514E-01
			SADT:	3.212E-01
			TAST:	2.239E-03
			TADT:	4.625E-01
			TRDT:	4.142E-02
			QADT:	0.000E+00
3	0.00	Sub_CBR2	Total:	2.727E-04

Appendix G

LCCA Construction Cost Calculations

Low Order Road

Total Depth = 510mm

Pavement Option 1: Unbound Granular				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.51	$ 19.47	$ 9.93
Type 2.1 (200mm)	m3	0.25	$ 103.35	$ 25.84
type 2.3 (250mm)	m3	0.26	$ 83.37	$ 21.68
C170 Binder	L	2.2	$ 1.80	$ 3.95
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 64.69

Total Depth = 310mm

Pavement Option 2: Modified Granular				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.31	$ 19.47	$ 6.04
Type 2.1	m3	0.15	$ 103.35	$ 15.50
type 2.3 CTB	m3	0.16	$ 153.27	$ 24.52
C170 Binder	L	2.2	$ 1.80	$ 3.95
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 53.31

Total Depth = 330mm

Pavement Option 3: Concrete				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.33	$ 19.47	$ 6.43
Type 2.1 (95mm)	m3	0.15	$ 103.35	$ 15.50
Leanmix (150mm)	m3	0.175	$ 250.38	$ 43.82
AMC00 Prime	L	0.4	$ 1.58	$ 0.63
S35E Binder	L	2.2	$ 1.84	$ 4.05
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 73.72

High Order Road

Total Depth = 730mm

Pavement Option 1: Unbound Granular				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.725	$ 19.47	$ 14.12
Type 2.1 (125mm)	m3	0.25	$ 103.35	$ 25.84
type 2.3 (680mm)	m3	0.48	$ 83.37	$ 40.02
C170 Binder	L	1.8	$ 1.80	$ 3.23
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 86.50

Total Depth = 480mm

Pavement Option 2: Modified Granular				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.48	$ 19.47	$ 9.35
Type 2.1	m3	0.23	$ 103.35	$ 23.77
type 2.3 CTB	m3	0.25	$ 153.27	$ 38.32
C170 Binder	L	1.8	$ 1.80	$ 3.23
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 77.96

Total Depth = 420mm

Pavement Option 3: Concrete				
Item	Units	Quantity	Rate	Cost
Excavation	m3	0.42	$ 19.47	$ 8.18
Type 2.1 (220mm)	m3	0.2	$ 103.35	$ 20.67
Leanmix (125mm)	m3	0.22	$ 250.38	$ 55.08
AM4 Prime	L	0.4	$ 1.58	$ 0.63
S35E Binder	L	1.8	$ 1.84	$ 3.31
14mm Agg	m3	0.01	$ 230.42	$ 2.30
7mm Agg	m3	0.004	$ 247.49	$ 0.99
			Total	$ 91.17

Appendix H

Project Risk Assessment

Project Risk Assessment

Activity	Hazard	Severity	Likelihood of incident	Risk Mitigation
Site Visit	Working under traffic	High	High	Wear PPE including Hi-Vis vest Observe road rules and look for traffic
	Sun damage	High	High	Wear sun safe clothing and sunscreen
	Eye damage	High	High	Wear sunglasses
	Tripping/Falling	Medium	Medium	Wear appropriate footwear (steelcapped boots)
Desktop Work	Eye strain from computer monitors	Medium	High	Take a break from the computer every 30 minutes to rest eyes
	Back injury of prolonged sitting at desk	Medium	Medium	Take a break from the computer every 30 minutes to stretch
	Dataloss	Medium	Medium	Ensure all documents are backed up using Google Drive
Operating vehicle	Car crash	High	Medium	Adhere to road rules and observe traffic conditions
	Refuelling fire	High	Low	Adhere to petrol station rules of not smoking or using mobile phone when refuelling